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CONTENTS

PAGES

McFARLANE, S. HANFORD. A study of the endoparasitic trematodes from marine fishes of Departure bay, B.C. 335-347

TEMPLEMAN, W. Fourth stage larvae of *Homarus americanus* intermediate in form between normal third and fourth stages 349-354

WILSON, C. B. *Argulus canadensis* from Cape Breton island 355-358

MOTTLEY, C. McC. A biometrical study of the Kamloops trout of Kootenay lake, *Salmo kamloops* Jordan 359-377

WHITE, H. C. Age determinations of salmon parr by effect of rate of growth on body proportions 379-382

PRITCHARD, A. L. Factors influencing the upstream spawning migration of the pink salmon, *Oncorhynchus gorbuscha* (Walbaum) 383-389

WHITE, H. C. The homing of salmon in Apple river, N.S. 391-400

BATTLE, HELEN I., A. G. HUNTSMAN, ANNE M. JEFFERS, G. W. JEFFERS, W. H. JOHNSON, and N. A. McNAIRN. Fatness, digestion and food of Passamaquoddy young herring 401-429

JULY-AUGUST

1936

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A Study of the Endoparasitic Trematodes from Marine Fishes of Departure Bay, B.C.*

By S. Hanford McFarlane
University of Illinois

(*Received for publication June 13, 1935*)

(*Contribution from the Zoological Laboratory of the University of Illinois, No. 482*)

ABSTRACT

In this paper fifteen species of endoparasitic trematodes of marine fishes of Departure bay, B.C., are described. Eight of the fifteen species described are new.

The fish examined were the more common shallow water fishes that could be obtained with a seine. The fishes belonged to the following families: Syngnathidae, Pleuronectidae, Scorpaenidae, Hexagrammidae, Ophiodontidae, Scorpaenichthyidae, Cottidae, Embiotocidae, and Pholidae.

The parasites recorded are *Prosorhynchus scalpellus* n.sp., *Prosorhynchus apertus* n.sp., *Rhipidocotyle elongatum* n.sp., *Pharyngora bacillaris* (Molin 1859), *Podocotyle abitionis* n.sp., *Podocotyle atomon* Odhner 1905, *Podocotyle reflexa* Odhner 1905, *Aporocotyle simplex* Odhner 1900, *Stephanostomum casum* (Linton 1910), *Stephanostomum tristephanum* n.sp., *Deretrema cholaeum* n.sp., *Telolecithus pugetensis* Lloyd and Guberlet 1932, *Dinurus nanaimoensis* n.sp., *Lecithochirium exodicum* n.sp., and *Genolinea laticauda* Manter 1925.

The collection of material was done in and around Departure bay, Vancouver island, British Columbia, during the summer of 1932. The author wishes to acknowledge his indebtedness to the Biological Board of Canada under whose auspices the work was done. The author is indebted to Dr. W. A. Clemens and Dr. H. B. Ward for suggesting the subject and for kind assistance; to Mr. G. V. Wilby for identification of host fishes; to Dr. H. W. Manter and Dr. H. S. Pratt for the loan of type and identified material.

The identification and study of the material collected were done at the Zoological Laboratory of the University of Illinois. The author is grateful to the Department of Zoology for the use of materials and apparatus. Especial gratitude is extended to Dr. Harley J. Van Cleave, under whose direction this work was done, for his unstinted assistance and advice.

The fish were obtained chiefly by seining at low tide. A few were caught on set lines and some ling cod (*Ophiodon elongatus*) were obtained from a commercial fisherman at Nanaimo. The fish were examined as soon as possible after being caught. It was found that keeping the fish in a live box for any long period was unsatisfactory as they voided the inner lining of the gut and with it any parasites

*Abstract of thesis presented as partial fulfillment of the requirements for the degree of Ph.D. at the University of Illinois, June, 1934.

that might have been present. The parts of the fish examined for parasites were the mouth, gills, stomach, intestine, and gall bladder.

The parasites obtained were killed in Schaudinn's corrosive sublimate. The majority of the worms were killed and fixed by being shaken in warm corrosive sublimate, while others were placed on a glass plate and stroked with a brush which had been dipped in warm water. After the worms were relaxed by the warm water, warm fixative was substituted for the water. The usual procedure for the removal of the corrosive sublimate by means of iodine was followed. The worms were preserved in seventy per cent alcohol. Both Delafield's Acid Haemotoxylin and Borax Carmine were used as stains, the former giving much the better results.

The types of the new species described in this paper have been deposited in the U.S. National Museum, paratypes at the Pacific Biological Station, Nanaimo, B.C., and in the author's collection.

ORDER **GASTEROSTOMATA**

FAMILY BUCEPHALIDAE

Prosorhynchus scalpellus n.sp. (Fig. 1, b, d, h, i, k).

Host: Scorpaenichthys marmoratus (Ayres) (giant marble sculpin).
Position. Intestine.

Specific Diagnosis. Length 0.61 to 0.78 mm.; width 0.14 to 0.22 mm. Body depressed anterior to uterus. Pharynx posterior to middle of body (58μ long by 32μ wide). Intestine clavate, anterior to pharynx, and without cellular projections into lumen. Vitelline follicles small, dorsal to internal organs, their posterior limit being the region of the ovary, their anterior limit being that of the uterus. Ovary globular, 52μ in diameter, immediately in front of anterior testis. Eggs in specimens examined were collapsed, 32 to 40μ long by 16μ wide. Testes posterior to ovary, equal in size, 0.06 mm. in diameter, contiguous, tandem or lateral. Cirrus sac thick-walled, 0.39 mm. from posterior end of body. Seminal vesicle originates outside of cirrus sac and enters that organ at its anterior end. Cirrus straight, surrounded by prostate glands, opening into genital atrium which is in the posterior part of the body. Genital pore subterminal on ventral surface.

Comparisons (table I). This species more closely resembles *P. facilis* than the other species of this genus. It differs from both *P. facilis* and *P. apertus* in being smaller in all measurements. The shape of the anterior portion of the body is unique, the position of the pharynx and the thick wall of the cirrus are other differences.

Prosorhynchus apertus n. sp. (Fig. 1, a, j).

Host. Ophiodon elongatus Girard (ling cod).
Position. Intestine.

Specific Diagnosis. Body elongate 1.4 to 2.07 mm., width in region of pharynx 0.22 to 0.36 mm. No spines observed as the cuticula had been sloughed off. Pharynx in middle of body 0.04 mm. in diameter. Oesophagus short. In-

testine sac-shaped with cellular projections into the lumen. About 30 vitelline follicles (0.044 mm. in diameter), in two rows, becoming confluent in region of anterior portion of uterus. Excretory pore terminal. Ovary anterior to testes, globular, 0.084 mm. to 0.117 mm. in diameter. Uterus in longitudinal folds. Eggs somewhat shrunken in specimens examined, 23 to 26μ long by 11 to 13μ wide. Testes in posterior part of body, oblique or tandem. Posterior testis slightly the larger. Diameter of anterior testis 0.091 mm. to 0.111 mm., of posterior 0.097 mm. to 0.123 mm. Cirrus sac 0.2 to 0.31 mm. long by 0.078 to 0.091 mm. wide, encloses seminal vesicle in its anterior portion. Seminal vesicle, an ovoid sac partly within the cirrus sac. Cirrus surrounded by prostate glands and having protoplasmic projections into its lumen. Genital pore subterminal on ventral surface.

Comparisons (table I). This species resembles *P. facilis*, the differences being chiefly concerned with measurements. The greatest morphological difference is that the seminal vesicle of *P. facilis* is a winding tube whereas in *P. apertus* it is an ovoid sac.

TABLE I. Comparison of species of *Prosorhynchus*

	P. facilis (Ozaki)	*P. apertus*	*P. scalpellus*
Length	1.85-4.6 mm.	1.4-2.07 mm.	0.61-0.78 mm.
Width	0.23-0.4 mm.	0.22-0.36 mm.	0.14-0.22 mm.
Rhynchus	Protrusile; 0.21 by 0.23 mm.	Protrusile; 0.78 by 0.104 mm.	Not protruded in specimens examined; 0.084-0.110 mm. by 0.123-0.130 mm.
Pharynx	In middle of body; 0.08-0.1 mm. in diameter.	In middle of body.	At level of testes; 0.058 by 0.032 mm.
Caecum	Tubular sac; anterior to pharynx; 0.37 mm. distal end from pharynx.	Pyriform sac; posterior to pharynx.	Sac-like; anteriad to pharynx.
Testes	Globular; ovoid; equal; 0.18-0.28 mm. diameter; anterior close to ovary; posterior—a little distance behind anterior.	Globular; ovoid; nearly equal; posterior usually slightly larger; tandem; close together; diameter anterior—0.111 average; posterior — 0.113 mm. average.	Globular; equal; 0.060 mm. diameter; contiguous.
Seminal vesicle	Winding tube at base of cirrus.	An ovoid sac at base of cirrus.	Curved tube at base of cirrus.
Cirrus	Long, narrow; 0.58 by 0.1 mm.	0.20-0.36 by 0.07-0.12 mm.	Thick-walled; 0.26 by 0.091 mm.
Genital pore	Ventral; subterminal; 0.12 mm. in front of posterior end.	Ventral; subterminal.	Ventral; subterminal.
Ovary	Globular; 0.13-0.17 mm. in diameter.	Globular; 0.08-0.11 mm. in diameter.	Globular; 0.052 mm. in diameter.
Eggs	35-40 μ by 21-25 μ.	23-26 μ by 11-13 μ.	32-40 μ by 16 μ.
Vitellaria	Lateral; covered by uterus.	Lateral to organs; linear; completely covered by uterus.	Dorsal to organs; linear; completely covered by uterus.
		Body anterior to uterus; round.	Body anterior to uterus; depressed.

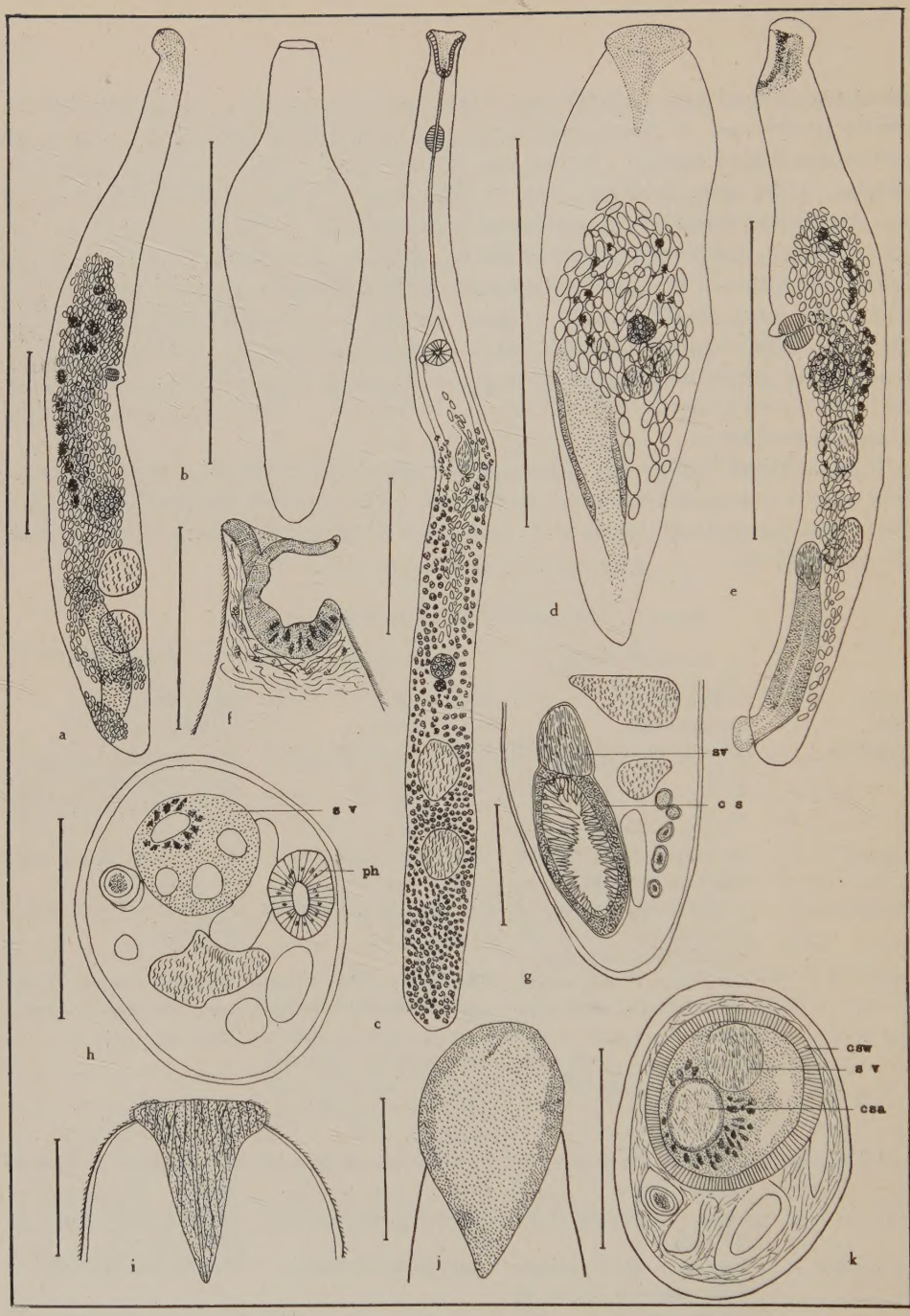

FIGURE 1. *Prosorhynchus apertus* n. sp.: a,—lateral view of adult; j,—sagittal section of anterior adhesive organ. *P. scalpellus* n. sp.: b,—lateral view of adult showing depressed anterior portion; d,—ventral view of adult; h,—transverse section near anterior of seminal vesicle showing relationship of pharynx; i,—frontal section of anterior adhesive organ; k,—transverse section of thick walled cirrus sac. *Pharyngora bacillaris*: c,—ventral view of adult. *Rhipidocotyle elongatum* n. sp.: e,—lateral view of adult; f,—longitudinal section of anterior adhesive organ; g,—longitudinal section showing seminal vesicle and cirrus with spines. In a, b, d, and e the scale equals 0.5 mm.; in f, g, h, i and k, 0.1 mm.; in j, 0.05 mm. and in c, 1.0 mm. Figures drawn with aid of camera lucida. *cs*—cirrus sac; *csa*—anterior end of cirrus sac; *csw*—wall of cirrus sac; *ph*—pharynx; *sv*—seminal vesicle.

Rhipidocotyle elongatum n.sp. (Fig. 1, e, f, g).

Host. *Ophiodon elongatus* Girard (ling cod).

Position. Intestine.

Specific Diagnosis. Body elongate, 0.86 to 1.5 mm. long by 0.11 to 0.25 mm. wide in region of pharynx. Pharynx anterior to middle of body, 0.032 to 0.046 mm. in diameter. Intestine sac-like with protoplasmic projections into the lumen. Excretory pore terminal. Vitellaria small separate follicles extending from region of ovary to anterior limit of uterus. Ovary anterior to testes and shell gland, globular, 0.165 to 0.171 mm. in diameter. Uterus voluminous, the eggs masking the internal organs; uterus opens into genital atrium. Eggs 0.029 to 0.032 mm. by 0.015 to 0.019 mm. Testes posterior to shell gland and ovary, oblique or tandem, ovoid, their length varying from 0.078 to 0.104 mm. and their width from 0.052 to 0.078 mm. Seminal vesicle contained within cirrus sac. Cirrus large with cellular projections into its lumen. Duct of seminal vesicle surrounded by prostate glands and opening into the genital atrium, which is at the posterior end of the body.

Comparisons (table II). This species more closely resembles *R. baculum* but differs from it in that the uterus extends anterior to the pharynx, the vitellaria are greater in extent, the eggs are larger and the anterior portion of the body is round, not depressed as in *R. baculum*.

TABLE II. Comparison of species of *Rhipidocotyle*

	R. baculum	*R. elongatum*
Length	0.7-0.9 mm.	0.86-1.5 mm.
Anterior adhesive organ	0.09-0.11 mm. in cross-section.	0.08-0.13 mm. in cross-section.
Pharynx	In middle of body; 0.02-0.04 mm.	Anterior to middle of body; 0.04-0.05 mm.
Ovary	Anterior to testes; 0.05 mm. in diameter.	Anterior to testes; 0.068 mm. in diameter.
Testes	Posterior to ovary; 0.07 mm. in diameter.	Posterior to ovary; 0.052-0.078 mm.
Uterus	Not reaching anterior to pharynx.	Reaches quite a distance anterior to pharynx.
Vitellaria	Irregular groups of about ten follicles on either side of pharynx.	Small follicles extending from ovary to anterior limit of uterus.
Cirrus sac	About one-third of body length in posterior end of body.	Less than one-third of body length in posterior end.
Eggs	19-21 μ by 11 μ	29-32 μ by 15-19 μ
Shape of body	Anterior part depressed, posterior part round.	Round in cross-section throughout length.

ORDER **PROSTOMATA**

FAMILY ALLOCREADIIDAE

SUBFAMILY **ALLOCREADIINAE**

Podocotyle abitionis n.sp. (Fig. 3, c).

Host. *Sebastodes* (sp.) (rock cod).

Position. Intestine.

Specific Diagnosis. Comparatively large, length 3.7 to 4.9 mm. Width

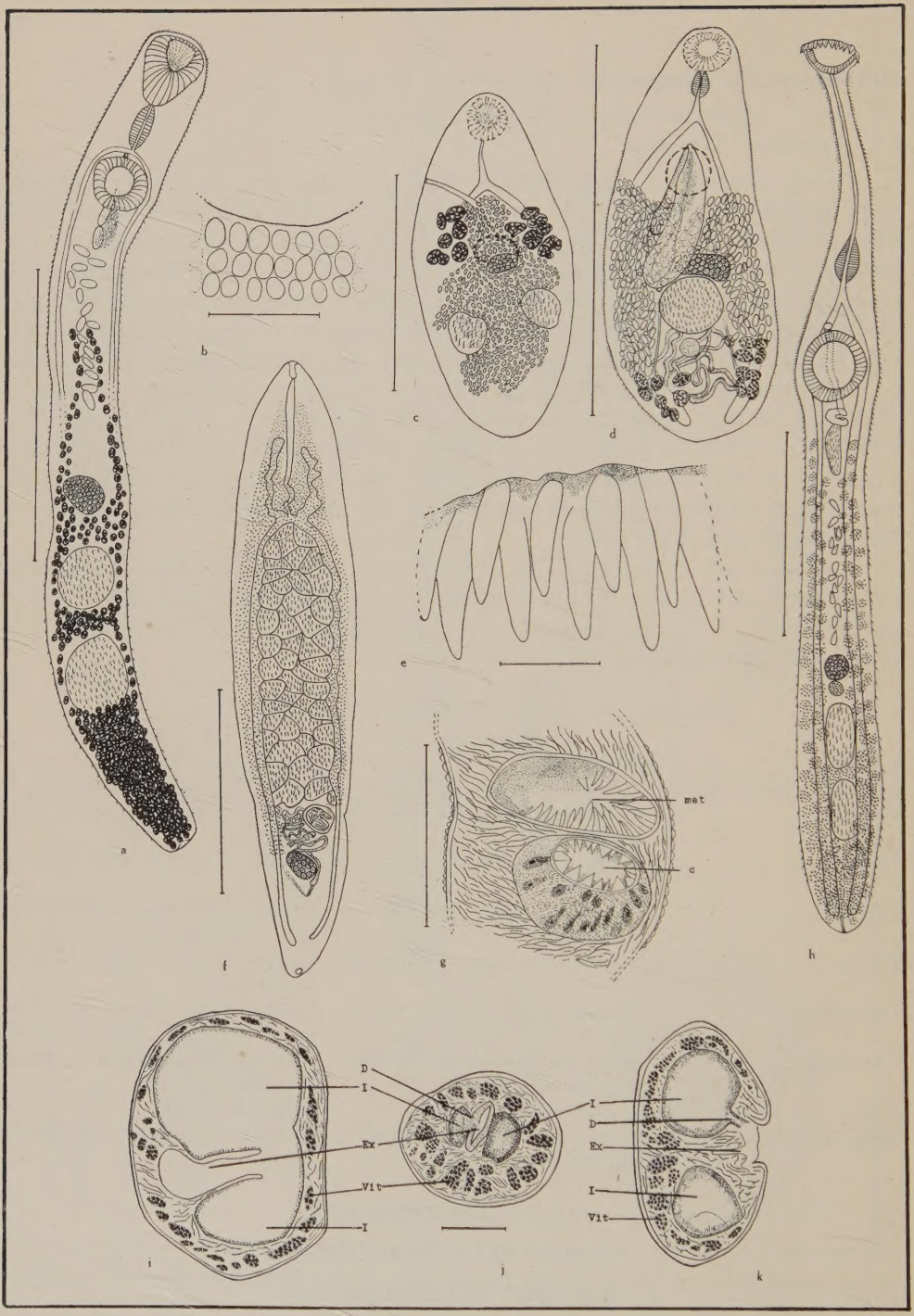

FIGURE 2. *Stephanostomum tristephanum* n. sp.: a,—ventral view of adult; b,—portion of crown of oral spines; *S. casum*: e,—portion of crown of oral spines; h,—ventral view of adult; i, j, and k,—transverse sections showing the union of the crura and excretory bladder in different individuals. *Deretrema cholaeum* n. sp.: c,—dorsal view of adult. *Telolecithus pugetensis*: d,—dorsal view of adult; g,—transverse section showing spines of metraterm and cirrus. *Aporocotyle simplex*: f. In a, c, d, and e the scale equals 1.0 mm.; in b and g, 0.05 mm.; in i, j, and k, 0.1 mm.; and in h, 0.5 mm. *c*—cirrus, *D*—duct, *Ex*—excretory bladder, *I*—intestine, *met*—metraterm, *Vit*—vitellaria.

one-sixth to one-twelfth of total length. Oral sucker 0.21 to 0.35 mm. in diameter and 0.16 to 0.24 mm. long. Opening of oral sucker subterminal on ventral surface. Acetabulum large, in anterior third of body, 0.56 mm. in diameter. Prepharynx short. Pharynx prominent, ovoid to elongate, 0.17 to 0.28 mm. long by 0.11 to 0.19 mm. wide. Oesophagus short, 0.19 mm., blunt processes projecting into lumen; oesophageal tissue extends a short distance (0.15 mm.) into the crura. The oesophagus bifurcates in the region of the acetabulum. The crura extend to the posterior part of body, epithelium of crura with fibrous cellular projections into lumen. Testes ovoid, 0.215 to 0.308 mm. by 0.168 mm. Cirrus posterior to acetabulum, posterior portion coiled; no prostate glands observed. Ovary trilobed, lobes directed posteriad, anterior to testes. Seminal receptacle dorsal to ovary. Vitelline reservoir between seminal receptacle and ovary. Laurer's canal opens to exterior on dorsal surface. Uterus much coiled, thickens to form metraterm anterior to crura. Eggs 0.065 to 0.078 mm. long by 0.032 mm. wide. Vitellaria around crura posterior to testes, not interrupted lateral to either testis, fill up intertesticular space and are lateral from ovary to ventral sucker.

Comparison (table III). This species most closely resembles *P. syngnathi* Nicoll 1913 but differs from that species in that the width in proportion to the length is less, the "neck" is shorter, the testes are much smaller, the cirrus sac extends posterior to the acetabulum, the eggs are smaller and the vitellaria are not interrupted at the posterior testis and occupy the intertesticular space.

TABLE III. Comparison of species of *Podocotyle*

	P. syngnathi Nicoll 1913	*P. abitionis*
Range of length	2.2-5.9 mm.	3.7-4.9 mm.
Width	0.78 mm.	0.40-0.70 mm.
Diameter—oral sucker	0.38 mm.	0.21-0.35 mm.
Diameter—ventral sucker	0.55 mm.	0.56 mm.
"Neck"	1.25 mm.	0.37-0.44 mm.
Prepharynx	Very short.	Short.
Pharynx—length	0.19 mm.	0.17-0.28 mm.
Oesophagus	0.17 mm.	0.19 mm.
Testes	0.57 by 0.47 mm.	0.215-0.308 mm. by 0.168 mm.
Cirrus	Short, stout, not going posterior to middle of acetabulum.	Posterior to acetabulum.
Ovary	Trilobate; 0.42 by 0.29 mm.; anterior to testes.	Trilobate; 0.164 by 0.206 mm.
Vitellaria	Interrupted at posterior testis; not in intertesticular space.	Not interrupted at posterior testis; in intertesticular space.
Ova	0.092 by 0.047 mm.	0.065-0.078 by 0.032 mm.

Podocotyle atomon (Rud. 1802) Odhner 1905 (Fig. 3, d)

Podocotyle reflexa Odhner (Fig. 3, b)

Specimens of *P. atomon*, accompanied by *P. reflexa*, were found in the intestines of the sculpin (*Leptocottus armatus*) and the pipefish (*Syngnathus griseolineatus*). *P. atomon* was found also in the blenny (*Epigeichthys atropurpureus*) and the greenling (*Hexagrammus stelleri*).

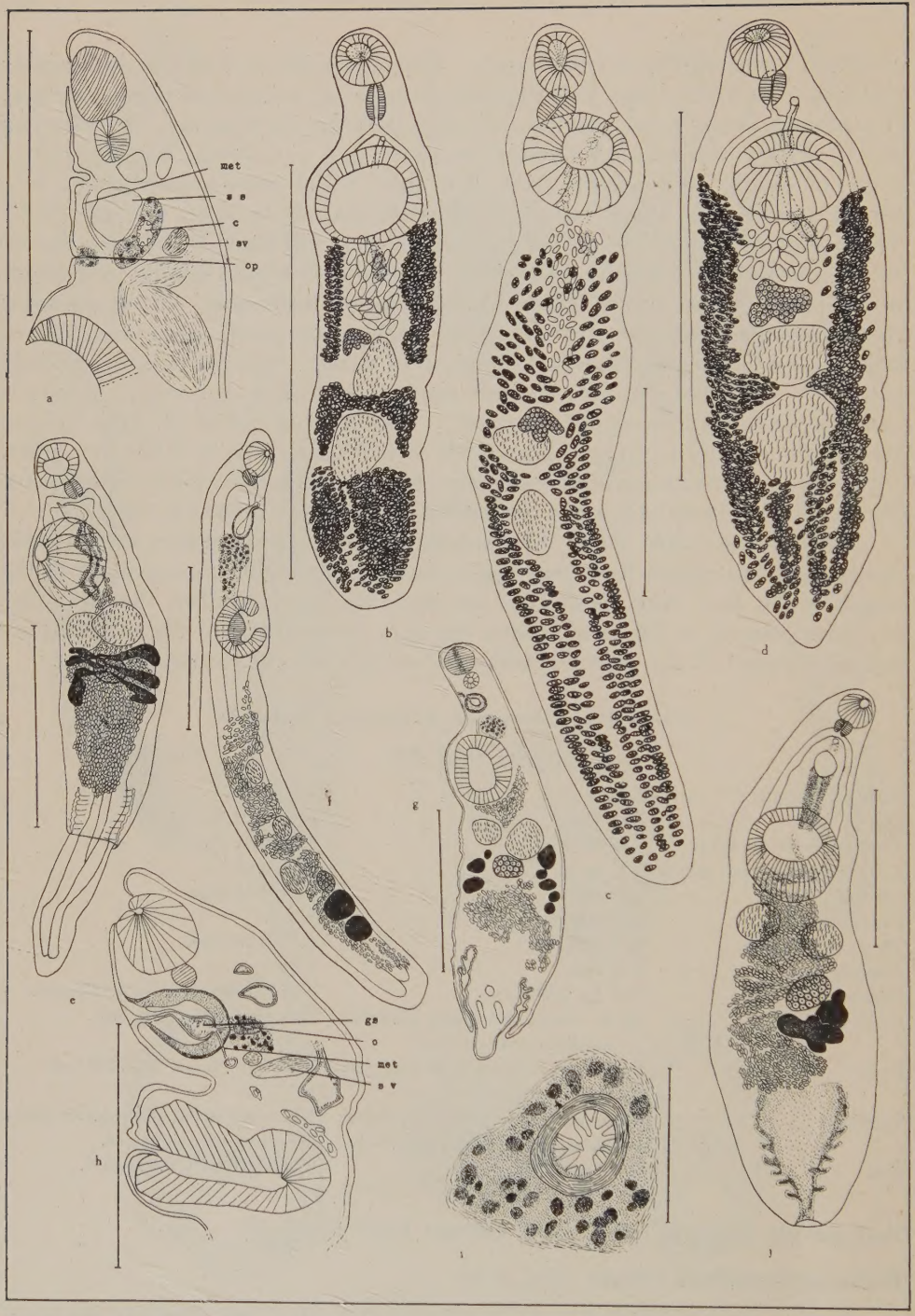

FIGURE 3. *Lecithochirium exodicum* n. sp.: a,—sagittal section of anterior end showing genital ducts; j,—ventral view of adult. *Podocotyle reflexa*: b,—ventral view of adult. *P. abitionis* n. sp.: c,—ventral view of adult. *P. atomon*: d,—central view of adult. *Dinurus nanaimoensis* n. sp.: e,—ventral view of adult; g,—longitudinal section showing relation of internal organs. *Genolinea laticauda*: f,—lateral view of adult; h,—sagittal section of anterior end showing genital ducts; i,—transverse section showing spined cirrus. In a to g and j the scale equals 1.0 mm.; in h, 0.5 mm.; and i, 0.1 mm. *c*—cirrus, *cp*—cervical pit, *gs*—genital sinus, *met*—metraterm, *sv*—seminal vesicle, *ss*—seminal sinus.

These two species are quite similar but may be separated by the break that appears in the vitellaria of *P. reflexa* lateral to each testis.

Among the specimens of *Podocotyle* in the author's collection are two individuals in which the vitellaria are interrupted at the posterior testis but on one side only of the anterior testis. This might be an indication that the specific arrangement of the vitellaria is a recent development and not completely established.

SUBFAMILY **LEPOCREADIINAE**

Pharyngora bacillaris (Molin 1859) (Fig. 1, c)

This species was found in the intestines of rock cod (*Sebastodes* sp.). This parasite has been recorded by Nicoll (1915) from four genera of fish. The host in which the author found this species and the locality are both new.

FAMILY APOROCOTYLIDAE

Aporocotyle simplex (Odhner 1900 (Fig. 2, f)

This species was found in the blood of a rock cod (*Sebastodes* sp.). This host and the locality, Departure bay, B.C., are new for the species. In a personal communication, Dr. Guberlet of the University of Washington has informed the author that this parasite is commonly found in the same genus of fishes in Puget sound. The author has not found this parasite to be very common in the locality from which it is reported.

FAMILY ACANTHOCOLPIDAE

Stephanostomum tristephanum n.sp. (Fig. 2, a and b)

Host. *Ophiodon elongatus* Girard (ling cod)
Position. Intestine.

Specific Diagnosis. Long, slender, 2.6 to 3.1 mm. long by 0.29 to 0.36 mm. wide. Suckers of equal size, 0.16 to 0.21 mm. Cuticula armed with small spines, most numerous anterior to acetabulum. Oral sucker surrounded by at least 140 spines, arranged in three rows. Anterior portion of body evidently contracted. Prepharynx short. Pharynx nearly globular, 0.078 mm. in diameter. Oesophagus short, 0.18 mm. Intestinal bifurcation in region of acetabulum; crura extend to posterior part of body. Each crux with filamentous projections into lumen. Indications of a uroproct were observed. Vitelline follicles small and profuse, uninterrupted posterior to ovary, anterior to ovary lateral, anterior limit posterior to acetabulum. Ovary round, smooth, 0.12 mm. in diameter. Uterus entirely anterior to ovary. Eggs 0.078 to 0.084 mm. long by 0.039 to 0.041 mm. wide. Testes globular, in posterior part of body. Seminal vesicle posterior to acetabulum. Cirrus sac 0.24 mm. long. Cirrus with projections into lumen. Genital pore ventral, immediately anterior to acetabulum.

Comparison (table IV). This species most resembles *S. lineatum* Manter 1934 and *S. microstephanum* Manter 1934. It differs from *S. lineatum* in body

size and number of oral spines, there being 50 to 52 in *S. lineatum*. It differs from *S. microstephanum* in that the vitellaria do not reach the acetabulum and the eggs are larger.

Stephanostomum casum (Linton 1910) (Fig. 2, e, h, i, j, k)

The finding of this parasite in the intestine of rock cod (*Sebastodes* sp.) at Departure bay, B.C., is to place on record a new host and a new locality for this species. The thing of morphological significance that was found in this species is the presence of a uroproct. This morphological feature has evidently been overlooked in the past as it was found in identified specimens that were kindly loaned by the U.S. National Museum, Dr. Henry S. Pratt, and Dr. H. W. Manter.

TABLE IV. Comparison of species of *Stephanostomum*

	S. microstephanum Manter 1934	*S. tristephanum* n. sp.
Length	2.09 mm.	2.8 mm.
Width	0.52 mm.	0.296 mm.
Oral sucker	0.230 mm.	0.201 mm.
Ventral sucker	0.190 mm.	0.23 mm.
Fore body	0.814 mm.	0.39 mm.
Prepharynx	0.172 mm.	0.026 mm.
Pharynx	0.168 mm.	0.078 mm.
Cirrus sac	0.213 mm.	0.240 mm.
Eggs	70-62 μ by 43-41 μ.	78-84 μ by 39-41 μ.
Oral spines	3 rows, at least 150. Irregular in shape. Maximum size: 10 by 6μ.	3 rows, at least 140. Irregular in shape. Maximum size: 12 by 8 μ.
Vitellaria	Confluent anterior to ventral sucker.	Do not reach ventral sucker.

FAMILY FELLODISTOMIDAE

Deretrema cholaeum n.sp. (Fig. 2, c)

Host. *Sebastodes* (sp.) (rock cod)
Position. Gall bladder.

Specific Diagnosis. Body ovoid, length 1.6 to 2.3 mm. Oral sucker 0.190 to 0.224 mm. in diameter. Pharynx muscular, 0.06 to 0.13 mm. long by 0.08 to 0.14 mm. wide. Oesophagus 0.28 mm. long, with cellular projections into lumen. Bifurcation of oesophagus anterior to ventral sucker. Crura not of equal length; each terminates in region of testis on that side. Ovary irregular, 0.16 mm. in diameter, dorsal to posterior margin of ventral sucker. Seminal receptacle prominent. Uterus ventral to internal organs, densely packed with eggs. Testes symmetrical, posterior to ovary, 0.30 mm. in diameter. Cirrus completely enclosed in cirrus sac. Seminal vesicle bipartite within cirrus sac, which extends from midline just anterior to ventral sucker to left lateral margin. Eggs 0.052 to 0.058 mm. long by 0.019 to 0.026 mm. wide.

Comparison (table V). This species agrees most closely with *D. fusillus* Linton 1910. The chief differences are in the size of the oral and ventral suckers and in the size of the eggs. The smallest eggs in the author's material are larger than the largest eggs of *D. fusillus*.

TABLE V. Comparison of species of *Deretrema*

	D. fusillus	*D. cholaeum* n.sp.
Length	1.82 mm.	1.6-2.3 mm.
Breadth	0.64 mm.	0.72-0.99 mm.
Oral sucker	0.25 mm.	0.19-0.22 mm.
Pharynx	0.07 by 0.08 mm.	0.062-0.112 by 0.089-0.140 mm.
Ventral sucker	0.43 mm.	0.308-0.336 mm.
Ovary	Oval, dorsal to right caudal margin of acetabulum. Seminal receptacle present.	Near midline, unlobed. Immediately dorsal to posterior margin of acetabulum. Seminal recepl tacle present. Laurer's cana- present.
Testes	Lateral a short distance back of acetabulum.	Lateral, about half way between ventral sucker and acetabulum.
Genital pore	On left side at level of bifurcation of intestine.	On left side of body. In region of bifurcation of intestine.
Cirrus	Short, cirrus pouch encloses seminal vesicle which is transverse to axis of body. Prostate glands not definite.	Cirrus sac elongate claviform. Wholly anterior to acetabulum. Elongate, extending from midline to lateral margin.
Vitellaria	Compact, subglobular, 6 or 8 on each margin lateral to ventral sucker.	Lateral, 6 to 8 follicles on each side lateral to ventral sucker.
Uterus	Very voluminous, filling almost all postacetabular space.	Very voluminous, filling almost all postacetabular space.
Ova	0.027-0.037 mm. by 0.015-0.024 mm.	0.052-0.058 mm. by 0.019-0.026 mm.

FAMILY MONORCHIDAE

SUBFAMILY **MONORCHINAE**

Telolecithus pugetensis Lloyd and Guberlet 1932 (Fig. 2, d, g)

This species has been found by Lloyd and Guberlet 1932 in *Cymatogaster aggregatus* (viviparous perch) at Friday harbour, Wash. The author reports it from the same host at Departure bay, B.C.

FAMILY HEMIURIDAE

SUBFAMILY **DINURINAE**

Dinurus nanaimoensis n.sp. (Fig. 3, e, g)

Hosts. *Parophrys vetulus* Girard (lemon sole) and *Scorpaenichthys marmoratus* Ayres (giant marbled sculpin)

Position. Intestine.

Specific Diagnosis. Length, exclusive of appendiculate portion, 1.51 mm. to 2.68 mm. long. Length of appendiculate portion dependent upon amount of extrusion. Oral sucker 0.168 to 0.212 mm. in diameter; ventral sucker 0.336 to 0.420 mm. Pharynx immediately behind oral sucker, diameter 0.089 mm. Oesophagus short. Crura extend to posterior part of body and into appendi-

culate portion. No projections into the lumen of the crura were observed. Two vitelline masses ventral to ovary. Each mass divided into three or four long ribbon-like structures radiating from a point near the ovary. Ovary ovoid, 0.24 mm. long by 0.13 mm. wide; posterior to testes. Uterus voluminous, does not enter appendiculate portion. Eggs 0.032 to 0.036 mm. long by 0.019 to 0.020 mm. wide. Testes symmetrical, immediately posterior to ventral sucker, round, smooth margined, 0.224 mm. in diameter. Seminal vesicle coiled, posterior end between testes. Prostate cells surround seminal vesicle between ventral sucker and cirrus sac; it enters cirrus sac close to but separate from metraterm. Cirrus sac pyriform, 0.224 mm. long by 0.112 mm. broad, thick-walled; does not extend posteriorly to anterior margin of ventral sucker. Ductus hermaphroditicus enlarged in posterior part of cirrus sac; filamentous projections into lumen. Genital pore ventral on level of posterior margin of oral sucker.

Comparison. This species differs from the described species of *Dinurus* in that the lobes of the vitellaria and the cirrus sac are shorter.

SUBFAMILY **STERRHURINAE**

Lecithochirium exodicum n.sp. (Fig. 3, a, j)

Host. Ophiodon elongatus Girard (ling cod).

Position. Stomach.

Specific Diagnosis. Body length 2.5 to 3.8 mm. Diameter of oral sucker 0.16 to 0.24 mm., of ventral sucker 0.40 to 0.59 mm. Ratio of oral to ventral sucker 2 : 5. Cervical pit present on ventral surface just anterior to ventral sucker. Pharynx 0.13 mm. in diameter. Oseophagus 0.05 mm. long with blunt projections into the lumen. Crura extend to posterior part of body and into the appendiculate portion. Inside the crura are projections into the lumen. Excretory pore terminal. The ducts leading to the excretory bladder are confluent in the region of the oral sucker. Testes symmetrical, anterior to ovary, 0.19 to 0.25 mm. in diameter. Seminal vesicle convoluted, not bipartite, prostate glands present only a short distance back of the seminal sinus. Pars prostatica has its inner wall covered with blunt protuberances. Ductus hermaphroditicus from seminal sinus to opening on ventral surface in region of intestinal bifurcation. Vitellaria compact masses, each mass being lobed. Ovary posterior to testes, 0.28 mm. in diameter. Uterus in short folds from the posterior part of the body to the ventral sucker. Metraterm empties into the ductus hermaphroditicus. Eggs 0.023 mm. long by 0.011 mm. wide.

Comparison (table VI). This species most closely resembles *P. synodi* Manter 1931 and an unnamed species described by Manter 1934. It differs from *P. synodi* in the ratio of the oral to ventral sucker and the eggs are about twice as large. It differs from the unnamed species in that the body is longer, the oral and ventral suckers are twice as large and the eggs are slightly larger.

TABLE VI. Comparison of species of *Lecithochirium*

	L. synodi Manter	*Lecithochirium* sp. Manter	*L. exodicum* n.sp.
Body length	1.5-4.8 mm.	1.5-1.8 mm.	2.5-3.8 mm.
Oral sucker		0.109 mm.	0.16-0.24 mm.
Ventral sucker		0.24-0.26 mm.	0.40-0.59 mm.
Ratio	1:2	1:2	2:5
Elevation oral sucker	Absent	Absent	Absent
Cervical pit	Present	Present	Present
Vitellaria	Lobes short and thick.	Lobes a little more elongate than in *Sterrhurus*.	Lobes short and thick.
Eggs	0.012-0.016 by 0.007-0.009 mm.	0.020-0.022 by 0.010-0.012 mm.	0.024 by 0.013 mm.

SUBFAMILY **DEROGENETINAE**

Genolinea laticaula Manter 1925 (Fig. 3, f, h, i)

This species was found in the stomach of *Scorpaenichthys marmoratus* (giant marbled sculpin). It was found by Manter in *Hippoglossus hippoglossus* on the Atlantic coast of North America. The finding of this parasite at Departure bay is the first record of it on the Pacific coast and the host is a new one.

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Fourth stage larvae of *Homarus americanus* intermediate in form between normal third and fourth stages.

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ABSTRACT

Thirteen out of 379 fourth stage lobster larvae reared at St. Andrews were definitely intermediate in form, in length of fourth stage period, and in habit, between the recognized third and fourth stages. They occur usually under unfavourable rearing conditions. The fifth stage produced by moulting of the intermediate fourth stage is intermediate in metamorphosis between normal fourth and fifth stages.

INTRODUCTION

The lobster undergoes its greatest metamorphosis in moulting for the third time to change from the 3rd to the 4th stage larva. As shown in figure 1 and table 1, the normal 4th stage lobster has lost the exopodites of the pereiopods and the long dorsal spines on the abdominal segments both of which are well developed in the 3rd stage. The claws have increased enormously in size, and the abdomen in width, the telson is shortened and broadened, the antenna very well developed and in general the larva has changed from a planktonic 3rd stage, swimming by the motion of its exopodites, to a form which spends much of its time on the bottom walking by means of its pereiopods and when it swims does so by the motion of its swimmerets.

In our experiments on the larvae of *Homarus americanus* at the Atlantic Biological Station, St. Andrews, 1933-1935, each lobster larva was kept separately in a glass container with about 250 cc. of sea water, and the larvae fed on plankton, chiefly small copepods. The exact date of moulting was observed both by noticing the new form of the larva and by observing the moulted shell.

In 13 cases in these three years out of 379 larvae reared to the 4th stage, larvae which had definitely moulted three times were found not to have attained the normal 4th stage of development, still retaining functional exopodites on the pereiopods. The long dorsal spines on the segments of the abdomen, absent on normal 4th stage lobsters, were also retained. The animal moved forward by the combined motion of the exopodites and the swimmerets, sometimes the exopodites alone functioning, and the pereiopods of the 4th stage larvae with long exopodites were never used for walking along the bottom. These larvae thus form an additional planktonic stage, instead of a stage also suited for walking about on the bottom as is the normal 4th stage lobster. The 4th stage

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larvae intermediate in form between normal 3rd and 4th stages will be referred to in further discussion as intermediate 4th stage larvae.

Williamson (1905) described an intermediate stage of the European lobster (*Homarus vulgaris*) similar to that described above for *Homarus americanus*. He did not, however, follow the larvae in their successive moultings after hatching, but selected them from the general collection of larvae which were developing in the hatchery at Aberdeen. Consequently he was undecided between two

TABLE I. Body proportions of 3rd

Table IA = Range Table IB = Average

3 Int.—3rd stage moulted shells from larvae which on moulting produced larvae intermediate between normal 3rd and 4th stages.
3 N. —3rd stage normal larvae.
4 Int.—4th stage larvae intermediate in form between normal 3rd and 4th stages.
4 N. —4th stage normal larvae selected at random.

Stage of larva	Number of larvae measured	Carapace length. Top of rostrum directly back. mm.	Carapace length. Bottom of eye socket directly back. mm.	Exopodite length on pereiopod					Length of chela	Length of longest dorsal abdominal spine, *i.e.*, dorsal spine on 5th segment of abdomen
				On 1st (cheliped)	On 2nd	On 3rd	On 4th	On 5th		
					Table	IA				
3 Int.	5	4.7-5.3	3.0-3.1	42-47	45-47	39-47	36-44	29-34	45-53	16-22
3 N.	5		3.1-3.5	41-47	47-48	44	35-42	27-31	51-53	22
4 Int.	11	5.6-6.8	3.3-4.2	12-44	12-35	12-40	9-37	9-23	59-67	9-19
4 N.	9	5.5-6.2	3.5-4.0	3-5	4-5	6	4-7	3-5	78-85	0
					Table	IB				
3 Int.	5	5.0	3.0	45	46	44	39	30	50	19
3 N.	5		3.3	44	48	45	37	28	52	22
4 Int.	11	6.0	3.6	27	25	25	25	20	65	15
4 N.	9	5.8	3.7	4	5	6	5	4	81	0

opinions—whether the intermediate larvae were precociously developed 3rd stage or backward 4th stage larvae. He says that "this intermediate stage was quite common among the larvae that were reared".

BODY PROPORTIONS

Table I gives the body proportions of 3rd stage larvae, of 4th stage larvae intermediate in form between normal 3rd and 4th stages and of normal 4th stage larvae selected at random.

All 4th stage larvae which still retained the dorsal spines on the last 5 abdominal segments were included with the intermediate 4th stage larvae. In the normal 4th stage larvae these dorsal spines are absent while in the inter-

mediate 4th stage they may be nearly as long as in the 3rd stage. Although in the ordinary 4th stage lobster the exopodites of the pereiopods have been reduced to mere functionless stubs bearing few or no setae, in the intermediate 4th stage larvae the exopodites are nearly as long as in the 3rd stage. In several 4th stage larvae these exopodites were quite as long as those of 3rd stage larvae. In many cases these exopodites on the pereiopods of intermediate 4th stage larvae bore perfectly normal fringes of setae while in others many of the setae,

and 4th stage lobster larvae, 1934

Proportions expressed as a percentage of the carapace length from the bottom of the eye-socket directly back.

Measurements of parts of the body are exclusive of the setae fringing them.
Measurements of exopodites include exopodite alone, not the projection of the basipodite.

Length of exopodite of uropod	Median length of telson excluding median spine	Length of telson from tip of corner spine to junction with abdomen	Telson width at base of median spine	Width of telson at junction with 6th segment of abdomen	Length of setae on telson measuring from mid point of telson	Length of endopodite of antenna from base of flagellum outwards excluding the 2 basal segments of endopodite
			Table	IA		
32-38	48-53	74-75	48-50	24-25	2-3	42-47
35-36	50-51	72-80	53-57	25-27	4	45-48
32-35	44-47	62-70	38-40	26	3-14	38-68
33-34	39-41	42-43	34-35	29-30	17-20	103-119
			Table	IB		
35	51	74	50	25	2	45
37	51	76	55	26	4	46
34	44	62	38	27	13	56
33	41	41	34	30	19	116

especially at the tips of the exopodites, had been lost. Correlated with the presence of long exopodites on the pereiopods of these intermediate larvae the rostrum was longer, the chela and the antenna much shorter than in the normal 4th stage larvae. The proportions of the telson were also intermediate between the 3rd stage and the normal 4th stage while the spine was present at the middle of the posterior border of the telson. This spine is also present in the 3rd stage larva but is absent in all normal 4th stage larvae. As seen in table IA, except for the possession of dorsal spines on the abdomen of all the intermediate 4th stage larvae, these larvae ranged from forms with long setose exopodites very much like the 3rd stage larvae to forms with short exopodites with few setae fringing them, these larvae being in their body proportions closer to the normal

4th stage than to the 3rd. The 3rd stage larvae which on moulting produced these intermediate forms were essentially similar to the 3rd stage larvae which moulted into the normal 4th stage, the essential character of the 3rd stage—the uropods, being present and normal in size (table I).

CONDITIONS OF PRODUCTION

One out of 70 fourth stage larvae reared at St. Andrews in 1933, eleven out of 134 fourth stage larvae reared in 1934 and one out of 175 fourth stage larvae reared in 1935 were intermediate in form between the normal 3rd and 4th stages possessing dorsal spines on the abdominal segments, functional exopodites on the pereiopods and the accompanying form variations discussed above.

It is noteworthy that while the lobster larvae used in the experiments of 1933 and 1935 were on the whole healthy, those used in the experiments which produced most of the intermediate larvae in 1934 were not particularly healthy, a much larger percentage of the controls dying than in the other years which produced few larvae intermediate between the 3rd and the 4th stages. These intermediate larvae in 1934 occurred mostly in experiments at other than normal conditions. One was produced in an experiment where only half of the usual amount of plankton was fed to the larvae, another at 5°-8° C., two kept at 8°-10° C., one at a salinity of 25 per mille, two at 22 per mille and one at 19 per mille. The remaining three occurred in an experiment at a favourable temperature of 15°-16° C., normal salinity of about 31 per mille and a suitable supply of copepods as food. The larvae used in this experiment, however, were not healthy, most of them dying before reaching the 4th stage and in the remainder the 3rd stage was prolonged far longer than was usual at this temperature.

These intermediate larvae were produced in several cases where the 3rd stage period was about twice as long as that of larvae moulting into normal 4th stage under the same conditions in the same experiment, in other cases the length of the 3rd stage period was the same both in the cases of the intermediate and of the normal 4th stage larvae under the same conditions in the same experiment.

GROWTH

In at least two cases the intermediate 4th stage larvae lived long enough to moult into the next stage. In the one case particularly observed, at a temperature of 19°-20° C. in 1935, a 4th stage larva of the extreme intermediate form with long spines on the dorsal part of the abdomen, and long setose functional exopodites etc., spent only 6½ days in the 4th stage while 8 normal 4th stage larvae under the same conditions in the same experiment spent an average of 12 days in the 4th stage. At the same temperature the 1st stage lasted 3½ days; the 2nd, 3¾ days; and the 3rd, 6½ days.

In the case of four 3rd stage larvae which moulted into the intermediate 4th stage form the average growth calculated on the basis of carapace length from the bottom of the eye-socket directly back was 21% while under favourable conditions fifteen 3rd stage larvae in one experiment gained 17.4% and in another experiment four 3rd stage larvae gained an average of 16.9% on moulting to produce normal 4th stage larvae.

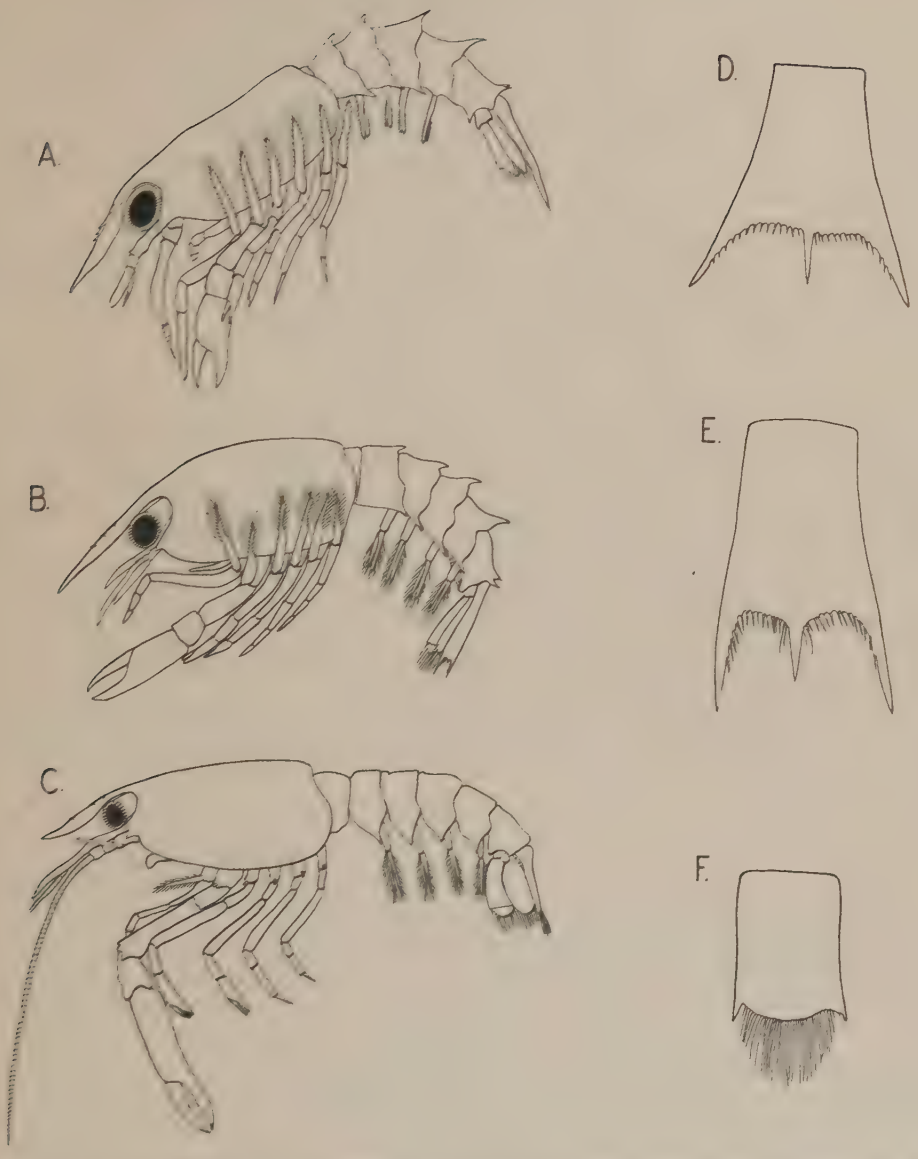

FIGURE 1. A. 3rd stage larva of *Homarus americanus* (after Herrick 1911, p. 339). B. 4th stage larva intermediate in form between 3rd and 4th stages. (The larva drawn is of the extreme type resembling the 3rd stage.) C. Normal 4th stage larva. D. Telson of 3rd stage larva. E. Telson of intermediate 4th stage larva (B). F. Telson of normal 4th stage larva (C).

N.B. No attempt has been made to give the correct number of setae on the appendages in A, B, and C. In D, E and F, however, the exact number of setae are shown. The larvae are not drawn to scale.

In two cases where definitely intermediate 4th stage larvae with long functional exopodites, etc., moulted to produce 5th stage larvae, these 5th stage larvae had lost the exopodites on the pereiopods, merely retaining functionless stubs bearing no setae. The length of the chela offers possibly the best chance of comparing this 5th stage with the normal 5th. In the two larvae mentioned above the length of the chela of the 5th stage larva was in both cases 91% of the carapace length measured from the bottom of the eye-socket directly back. In the normal 4th stage larvae whose proportions are shown in table I the chela averaged 81% of the carapace length. In one of the experiments of 1934 selected at random for comparison in five normal 4th stage larvae the chela length equalled 88% of the carapace length while in five 5th stage larvae of the same experiment the chela length was equal to 99% of the carapace length.

CONCLUSIONS

From the foregoing data it is evident that under certain conditions the purely planktonic larval life of the lobster may include not only the first three stages but a fourth stage which retains the functional setose exopodites on the pereiopods, dorsal spines on the abdominal segments, the long rostrum and telson, short antennae and small chelae characteristic of the 3rd stage.

These 4th stage larvae intermediate in form between the normal 3rd and 4th stages occur but rarely under favourable conditions but are often found if the larvae are not healthy or under other unfavourable conditions such as too low temperature or salinity, or too little food.

The 4th stage period in the intermediate 4th stage larva is only a little over half as long as that in the normal 4th stage, being very similar in length to the previous planktonic 3rd stage.

Growth in length on moulting from the 3rd stage is approximately the same in the case of both the intermediate and the normal 4th stage larvae. It is probably a little greater in the case of the intermediate 4th stage since the general metamorphosis of the body has been less than in the case of the normal 4th stage.

The 5th stage larva produced by the moulting of the intermediate 4th stage larva is intermediate in metamorphosis between the normal 4th and 5th stages.

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Argulus canadensis from Cape Breton Island

By Dr. C. B. Wilson
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ABSTRACT

Adult males, as well as young males and females, are described for the first time. The male has the most complicated secondary sexual apparatus so far described for species of *Argulus*. The immature differ markedly from the adults.

Twenty years ago two parasites taken from whitefish in Lake of the Woods were identified as a new species, *Argulus canadensis*, and were described and figured in the Bulletin of the U.S. Bureau of Fisheries, Vol. 39, p. 348. Since that time many new specimens have been obtained by various members of the Biological Board of Canada and sent to the author through Dr. A. H. Leim, Director of the Station at St. Andrews, N.B. These specimens came from lake Ainslie and the Margaree river on Cape Breton island and were taken chiefly from brook trout. A few were also found upon sticklebacks, perch and suckers, showing that when abundant they use any available fish as host. Recently over 900 specimens, which had been collected by Dr. J. M. B. Corkill during the summer of 1935, were sent to the author by the Biological Board. These included as many males as females and most of them were only quarter or half grown. Since the two original specimens were females and the male has remained unknown up to the present time, a description and figures of it are here given.

Argulus canadensis Wilson

The Adult Male

Carapace similar to that of the female but longer, almost reaching the abdomen, while in the female it only reaches the middle of the third thoracic segment. The cephalic area is one-half longer than wide and projects forward prominently. The compound eyes are removed farther from the frontal margin and the median eye still farther behind them. The posterior lobes are curved inward at their tips, and although the posterior sinus between them is usually broad it is occasionally so narrow that the lobes meet on the midline. The respiratory areas are an exact copy of those in the female, the outer one club-shaped, the larger end anterior, while the handle of the club extends backward along the outer margin of the inner area. The latter has a rounded protuberance at its inner anterior corner, and is somewhat enlarged posteriorly. As was remarked in describing the female the shape and arrangement of these areas is so unlike that of other species of the genus as to afford complete identification.

The abdomen is greatly elongated, two and a half times as long as wide,

with nearly straight sides. The posterior sinus reaches the centre of the abdomen and the anal laminae are subbasal and nearly spherical, each with 3 setae. As would be expected the testes are quite elongate and often reach behind the base of the posterior sinus.

The appendages are similar to those of the female with the following differ-

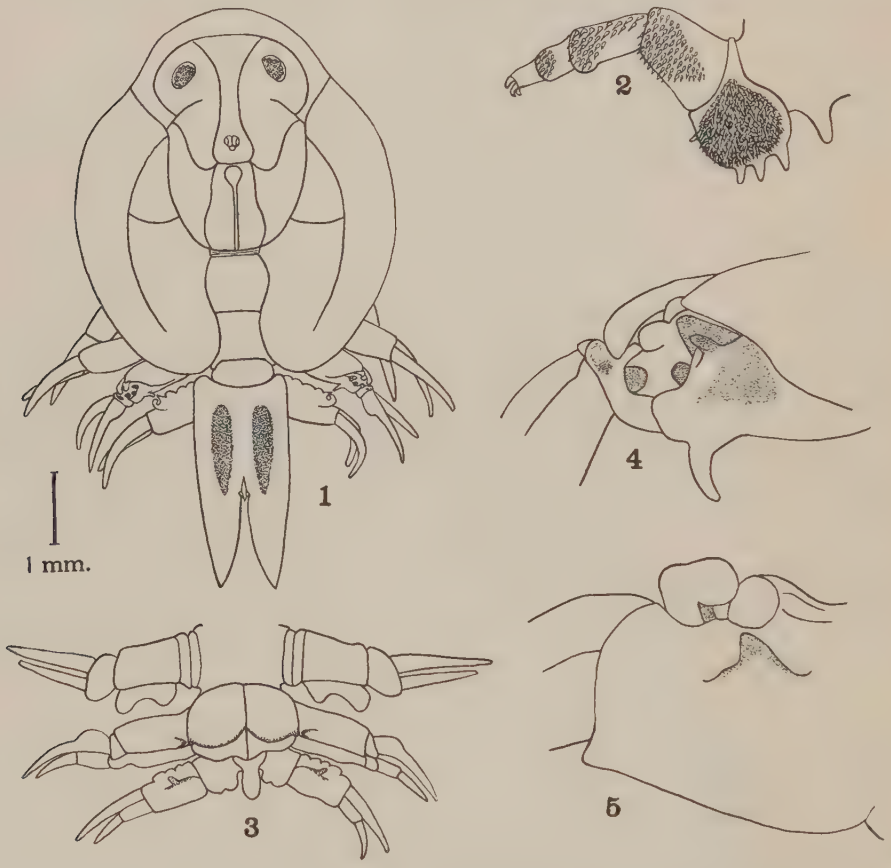
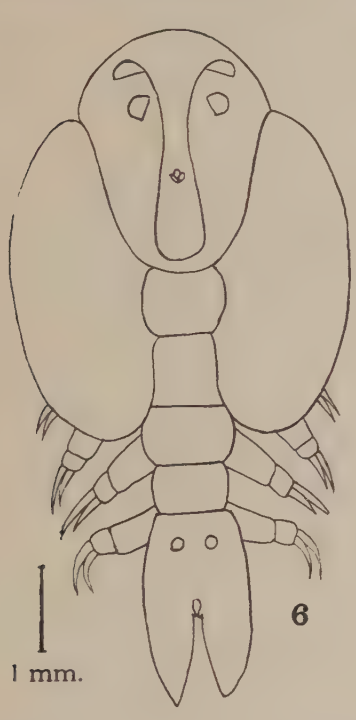


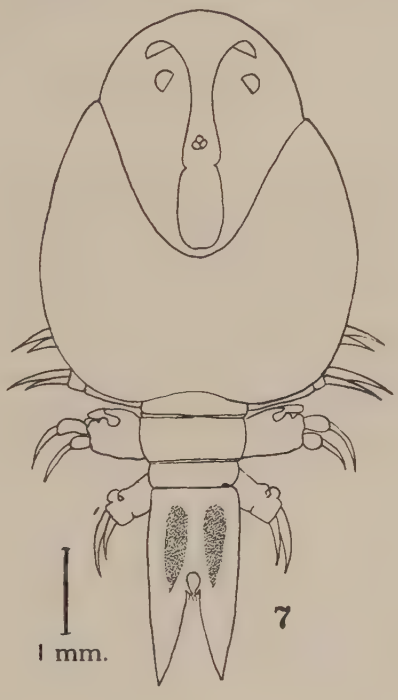
FIGURE 1. Dorsal view of fully grown male. FIGURE 2. Maxilliped. FIGURE 3. Ventral view of last three pairs of legs. FIGURE 4. Dorsal view of third basipod. FIGURE 5. Dorsal view of fourth basipod.

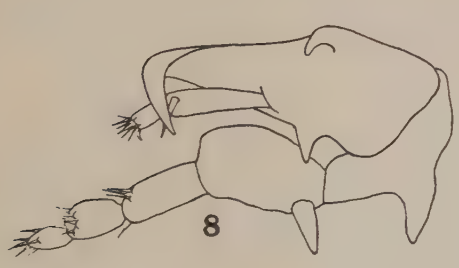
ences. The second antennae are four-segmented, the basal segment is much enlarged and has a stout posterior spine close to its proximal end. The second, third and fourth segments diminish in size distally, each with numerous setae at the distal end. The raised area on the basal plate of the maxilliped is relatively larger and nearly circular in outline, and the teeth on the posterior margin of the plate are shorter, stouter and rather blunt. As in the female there are also spiny areas at the distal ends of the basal and third segments, and over most of the surface of the second segment. The supporting ribs of the sucking disks have exactly the same pattern as in the female, an oblong basal joint and 10 or 11 disks overlapping like shingles and diminishing in size distally.

But the chief interest in this male centres in the secondary sexual characters.

On the ventral surface of the second legs at the posterior margin of the basipod is a wide curved flap which is concave posteriorly. Extending across the ventral surface of the thorax between the bases of the third legs is a swollen pad which overlaps the fourth segment posteriorly and the second segment anteriorly. Covering the ventral surface of this pad is a pair of chitin plates, joined on the







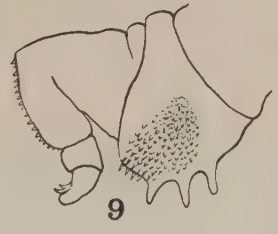


FIGURE 6. Dorsal view of half grown female. FIGURE 7. Dorsal view of half grown male. FIGURE 8. First and second antennae. FIGURE 9. Maxilliped.

midline and not reaching the posterior margin of the pad. The posterior margins of these plates are coloured bright orange, deepest at the outer corners, each of which ends in a rounded knob. From beneath the centre of the pad a wide and tongue-shaped lamella extends backward between the bases of the fourth legs and onto the ventral surface of the abdomen.

On the ventral surface of the basipod of each third leg is a similar chitin plate, joined proximally with the plate on the central pad, not reaching distally the bases of the rami, and posteriorly falling short of the margin of the basipod.

These basipod plates also have bright orange margins, deepest at the distal corners. On the dorsal surface of the basipod of each third leg at the distal end is a large semen receptacle. Its opening is surrounded by three orange chitin knobs, with a fourth on the anterior edge. In front of the opening is a long finger-like process, pointing outward along the anterior margin of the leg. Behind the opening on the posterior margin of the basipod is a curved and pointed process extending backward toward the forceps on the fourth leg. On the ventral surface of the fourth leg is a single orange process near the centre of the basipod and at the anterior distal corner is a chela made up of two soft spherical processes.

Taken as a whole this secondary sexual apparatus is more complicated than that of any *Argulus* male thus far described, and since it is visible in both dorsal and ventral views it helps greatly in identification. The colour of the male is creamy white, the eyes and the testes cinnamon brown, the secondary sexual apparatus fringed with bright orange. Total length 8.50 mm. Carapace 5.20 mm. long, 4.50 mm. wide.

Young Males and Females

The half grown males and females, especially the former, differ so much from the fully grown ones in general appearance that they were at first regarded as a separate species. A dorsal view is shown of both sexes, with the carapace slightly overlapping the third thoracic segment in the female and not quite reaching its anterior margin in the male. The posterior sinus is very shallow in the male and the two posterior lobes are partly fused across the dorsal surface of the second segment. The cephalic area is as prominent in the female as in the male and the eyes are considerably removed from the frontal margin. The second antennae are 4-segmented in both sexes and the maxillipeds are shorter and stouter than in the full grown adult. But in spite of these differences the respiratory areas and the supporting ribs of the sucking disks are exactly the same as in the mature specimens and identify the species beyond a doubt.

REMARKS

In transmitting the specimens collected during the summer of 1935 those taken from each fish were placed in a separate vial. Some idea of the abundance of the parasites can be gained from the following list of figures which represent the numbers of specimens in ten of the vials. 16 : 32 : 33 : 49 : 53 : 53 : 55 : 98 : 154 : 282, a total of 825 on 10 fish.

Ordinarily there are not enough of these parasites upon any one fish to occasion trouble but they became a serious menace to every one of the above ten fish. And the worst of it is that the detriment works in both directions; the parasites have the pernicious habit of congregating upon weakened or diseased fish, thereby making their death doubly sure. On the other hand a fish whose blood has been sucked by even a few of these parasites is just so much weakened and hence the more likely to contract disease or to succumb to adverse conditions.

A Biometrical Study of the Kamloops Trout of Kootenay Lake, *Salmo kamloops* Jordan

By C. McC. Mottley
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(*Received for publication March 28, 1936*)

ABSTRACT

A study was made on 216 specimens of Kamloops trout ranging from 10 cm. to 75 cm. in length obtained from the angling fishery of Kootenay lake and the spawning run in the Lardeau river. Twenty-four characters commonly used in the description and differentiation of the taxonomic groups of salmonoid fishes were investigated and a biometrical analysis of the differences due to size and sex is presented. The analysis of the data shows that the form of an individual undergoes consistent change; its form and the relative proportion of many body parts are probably the resultant of a number of factors which are intimately related with the rate of growth and the degree of sexual maturity. In many characters, e.g. the head proportions and body depth, the mature males differ appreciably from the females. The results indicate that the characters investigated must be used with caution in the taxonomic study of fishes. In comparing specimens of trout for taxonomic purposes individuals of the same size, age, sex and degree of maturity should be used if possible.

INTRODUCTION

According to a recent check-list (Jordan, Evermann and Clark 1930), thirty-three species of trout, *Salmo*, have been recognized in western North America. Aside from the qualitative differences between the two main groups, the rainbows and the cutthroats, the separation characters are all based on quantitative differences. As Kyle (1900) has pointed out, the differentiae possessing taxonomic significance emerge only after the primary and secondary sexual differences and the differences due to size, age and habitat have been eliminated. Since no one has ever attempted to do this for the trout of western North America, it seemed desirable to make a critical study of the quantitative characters used in the classification and description of the genus. The present paper is intended, therefore, to give the main results of a biometrical analysis of a single population of trout with special regard to the differences due to size and sex, in order that it may serve as a foundation for further studies in this field, particularly an analysis of the differences due to habitat.

The Kamloops trout of Kootenay lake, described by Jordan and Snyder (1908) and by Dymond (1932), were selected for the study because they could be obtained in fairly large numbers over a considerable range of size. The characters investigated included twenty measurements of the head, trunk, tail and fins, and four numerical characters, namely, the number of gill rakers, branchiostegal rays, dorsal and anal fin rays. The number of scale rows has already been treated by Mottley (1934).

A list of the characters investigated together with the abbreviation used in the discussion and a reference number to figure 1, where the characters are shown graphically, is given in table I. The characters have been arranged into two groups, continuous variables, such as body proportions, which may assume within the limits of their range any value whatsoever, and discontinuous variables or counts, such as the number of fin-rays, which can assume only certain clearly defined whole numbers. This list is by no means a complete set of the morphological characteristics of a population, but it serves as a source from which to draw the materials that have been usually employed not only in description or characterization but in taxonomic differentiation as well.

TABLE I. Index to the characters

Character (abbreviation)	Reference number Figure 1	Character (abbreviation)	Reference number Figure 1
Continuous variables		Continuous variables	
Size		Trunk and tail proportions	
Standard length (SL)		Distance from snout to dorsal fin (SnD)	2a.
Total length (TL)		Distance from snout to ventral fin (SnV)	2b.
Head proportions		Depth of body (BD)	2c.
Length of head (HL)	1a.	Width of body (BW)	2d.
Depth of head (HD)	1b.	Length of caudal peduncle (CPL)	2e.
Diameter of eye (E)	1c.	Depth of caudal peduncle (CPD)	2f.
Length of snout (Sn)	1d.		
Length of maxillary process (Ma)	1e.	Fin proportions	
Width of interorbital (I)	1f.	Height of dorsal fin (DHt)	3a.
Distance from snout to occiput (SnO)	1g.	Length of base of dorsal fin (DBa)	3b.
		Height of anal fin (AHt)	3c.
		Length of base of anal fin (ABa)	3d.
		Length of pectoral fin (PL)	3e.
		Length of ventral fin (VL)	3f.
		Length of caudal fin (CL)	3g.
Discontinuous variables			
Gill raker count		Dorsal fin ray count	
Branchiostegal count		Anal fin ray count	

SAMPLING

The material on which the study was made consisted of 216 specimens obtained from Kootenay lake and its tributaries in the years 1927-28-29. The majority of the data were secured in June and July, 1928 and 1929, from 196 specimens caught by anglers. The measurements and counts were made on the fresh material and the fish were returned to their owners. Twenty larger fish, ten males and ten females, were caught at spawning time at the Gerrard hatchery on the Lardeau river in May, 1927. These were preserved and sent to the Royal Ontario Museum of Zoology, where they were measured and are now stored.

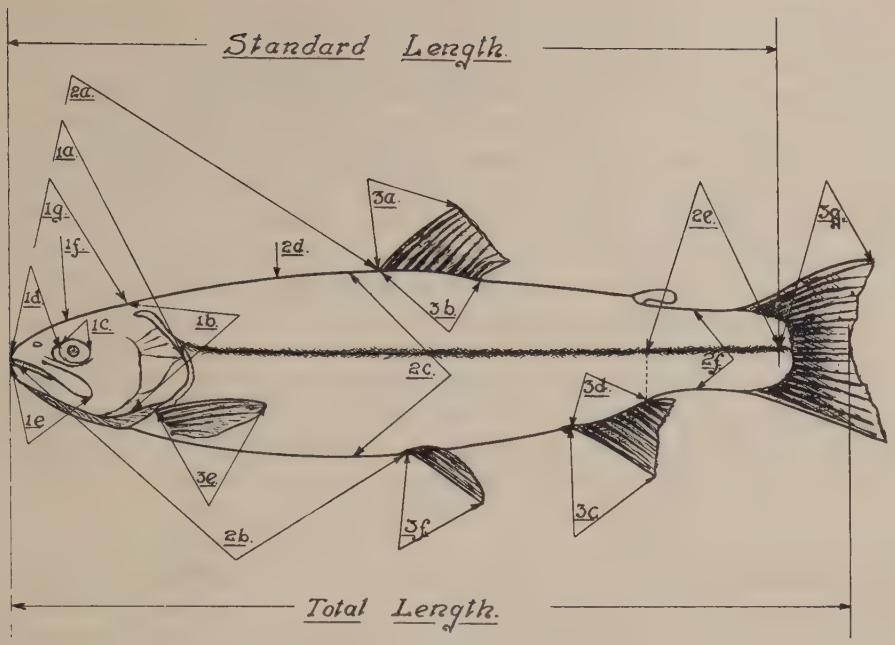

FIGURE 1. Kamloops trout, showing position of the various characters of the continuous-variable type used in this study; numbers and letters as in table I.

PRESENTATION OF THE DATA

The data for each sex were grouped according to size and arranged into an array of size-groups based arbitrarily on 100 mm. intervals of the standard length measurement. The number of fish in each group, the mean SL and the range are shown in table II. The arbitrary nature of the grouping is indicated by Roman numerals.

TABLE II. Showing the number of specimens, the mean standard length and the range of each size group in a sample of 216 Kamloops trout from Kootenay lake

Group no.	Males				Females				
	Number of specimens	Mean standard length	Range			Number of specimens	Mean standard length	Range	
			Min.	Max.				Min.	Max.
II	22	177.5	154	200		28	171.2	104	189
III	21	257.0	203	292		36	258.8	213	297
IV	17	346.8	301	396		29	338.2	301	396
V	3	435.(0)	408	460		8	465.2	420	490
VI	11	546.2	502	583		11	559.6	502	593
VII	13	637.8	602	690		14	622.6	601	657
VIII	3	748.(0)	736	758		not represented.			
Total	90				Total	126			

The raw data were arranged according to the size and sex of the specimens and have been deposited in the library of the Royal Ontario Museum of Zoology

where reference may be made to them. Several specimens were preserved and are also available at the Museum.

The raw data were reduced and the mean values and other statistical constants were calculated. The relation between the size of a body part or character and the body itself has been calculated and expressed as a percentage. In order to facilitate the presentation of the data and the appreciation of the relationships between the groups graphical methods were employed. Only those charts having a significant bearing on the discussion, however, are presented herein. The charting of the data falls into three different types:

1. The logarithmic presentation.

The mean values for males and females were plotted separately for each character on a double-log grid. The X-axis was used for the standard length mean-values, and the Y-axis was used for the mean-values of the character being considered. The logarithmic presentation allows the plotting of an extended size range within the compass of a small chart and depicts the true relationship between the mean-value of the character and the mean-value of the standard length. This type of chart also affords a means of studying the change between the rate of growth of the character and the growth of the body. The rate of change is described by the slope of the line, and this slope has been calculated for various characters from the following equation which only applies to the values as plotted on logarithmic paper:

$$Y = bX^k$$

where Y = the character
X = the standard length (SL)
b = a constant describing the point at which the line intersects the Y-axis
k = a constant describing the slope of the line.

Because this equation holds only for straight line relationships the trend of the central tendency lines in the charts may be described mathematically by calculating the value of k for certain segments. The majority of the charts were found to show an inflection of the curve between group III and group IV. Since this inflection is probably the result of approaching maturity and has real biological significance it has been found expedient to calculate k for two segments of the curve. Consequently for the purpose of description the k-values for the slope of the line between group II and group III and for the slope between group IV and group VII have been calculated separately. The first segment has been designated A and represents the transition from the juvenile to the immature adult stage; the second has been designated B and represents the transition from immature to mature adult.

The interpretation of the value of k is as follows:

(a) When k has the value of 1 the character or structure may be said to be growing at the same rate as the body (SL). This has been called "isogony" by Huxley (1932).

(b) When k has a value greater than 1 the character may be said to be

growing at a faster rate than the body. Pézard (1918) has described this condition as "heterogony" and Huxley (1932) has given it the special designation of "positive heterogony".

(*c*) When *k* has a value less than 1 the character may be said to be growing at a slower rate than the body. This has been termed "negative heterogony" by Huxley (1932).

Throughout the analysis of the data values of *k* falling between 0.95 and 1.06 have been considered to describe the isogonous condition. Although this arrangement suffices for the purposes of description, the significance of differences in the value of *k* remains to be determined for a more critical analysis.

A measure of variation has been added to these charts for the purpose of comparing observations on samples containing only a few specimens from other localities with the Kootenay lake population. Two lines above and two lines below the heavy, central tendency line are shown. These are the S_1 and S_2 lines, where

$$S_1 = 1x\sigma \text{ (standard deviation)}$$
$$S_2 = 2x\sigma$$

Theoretically in a sample consisting of six observations four may be expected to fall between $+S_1$ and $-S_1$, while one should fall between $-S_1$ and $-S_2$ and one between $+S_1$ and $+S_2$, if the two populations are identical.

2. Standard length indices (ŚL′).

The indices based on the standard length were plotted on the ordinary arithmetic grid. The mean standard length values of the arbitrary size groups have been given a fixed position on the X-axis, just as if the mean-values were the mid-values in each 10 cm. interval. The indices for the various characters have been plotted along the Y-axis in relation to the appropriate size group. In this way the proportions of fish of the same general size were compared and the trend from group to group was traced.

3. Frequency distributions.

The data concerning the four numerical characters or discontinuous variables were plotted in the form of frequency distributions.

ANALYSIS OF THE DATA

For the purposes of analysis the data may be considered under continuous and discontinuous variables. There is little evidence to suggest that the latter have different values in males and females or that the characters change with growth in the range of size considered in this study. The continuous variables, on the other hand, change noticeably with size and certain of the characters are quite different in the two sexes.

Continuous Variables

The continuous variables may be conveniently analyzed under two separate headings. Under the first the salient features of each character will be pointed

out, but these features are by no means intended to exhaust the information which has been incorporated in the figures and tables. Much of this information will be appreciated as more data concerning other populations of trout are gathered and analyzed. Under the second heading an attempt will be made to draw together the salient features into a comprehensive picture showing the changes in the form of the Kamloops trout concomitant with the change in size in both sexes.

The actual dimensions of the various characters, in relation to size, provide a static view of the form. Thus fish of a certain size range may be characterised by an index based on some datum of comparison such as the standard length (SL) or the length of the vertebral column. But Huxley (1932) says, "to neglect the fundamental fact of change of proportions with absolute size, and proceed as if certain arithmetic (percentage) proportions were immutable 'characters' of the species, may lead to serious error." The logarithmic presentation of the mean values obviates this difficulty and provides a dynamic expression of the change of the characters with size. In order to describe form-change, it is necessary to present a series of pictures, each depicting a certain stage in development and to include at the same time a factor describing the direction of the change. The SL′ serve the first purpose, the values of k the second.

Since this paper deals with the major trends of form-changes, rather broad size groupings have been made, but certain of these groups may be chosen to represent the characteristic phases of development. Thus group II is selected to illustrate the juvenile condition, and groups III to VIII represent the adult condition. Owing to the variation which accompanies the onset of maturity, the adult group may be divided into two parts, immature adults and mature adults. Since it is possible to have two trout of the same size, one of which is immature and the other mature, the analysis of the characters on this basis is very complex. However, there is a greater proportion of immature adults among the smaller fish and group III and group IV may be taken as representative of this stage. Group VII is chosen as the representative of the mature adults.

HEAD PROPORTIONS

Length of head. The head-length dimensions of the Kootenay lake Kamloops trout are represented by two characterizations, viz., HL and SnO (table I). From a study of the figures it was noted that these two characters follow similar trends with regard to the SL′ which are shown in detail for the two sexes. The logarithmic charts also showed the similarity between HL and SnO. For the purposes of discussion then, the HL will be taken as the characteristic length dimension of the head, partly because it is the one more commonly used by ichthyologists.

The curves in figures 2 and 3 show two distinct trends, for which the values of k were calculated. The k-values are given in table III, from which it may be seen that the slope A shows negative heterogony and the slope B positive heterogony in both sexes. In other words the head is growing in length at a slower rate than the body in the case of smaller trout, and at a faster rate than the body in the larger specimens. An examination of the original data showed that the

males had a slightly higher average value than the females in group III. The raw data also revealed a significantly higher variability among the males. Thus the indices calculated for individual cases showed that the head length of the males of 25 cm. in length (SL) ranged from 20 per cent to 25 per cent of the SL, whereas the females 25 cm. in length ranged from 20 per cent to 23 per cent.

TABLE III. Values of k for the head dimensions describing the slope of two segments of the central tendency lines in the logarithmic charts (unpublished)

	A		B	
	Group II to III		Group IV to VII	
Character	Males	Females	Males	Females
HL	0.84	0.76	1.3	1.2
SnO	0.83	0.72	1.3	1.1
Sn	1.0	0.77	1.7	1.5
Ma	0.80	0.69	1.5	1.3
HD	0.88	0.78	1.3	1.2
I	1.0	1.0	1.4	1.3
E	0.77	0.65	0.60	0.51

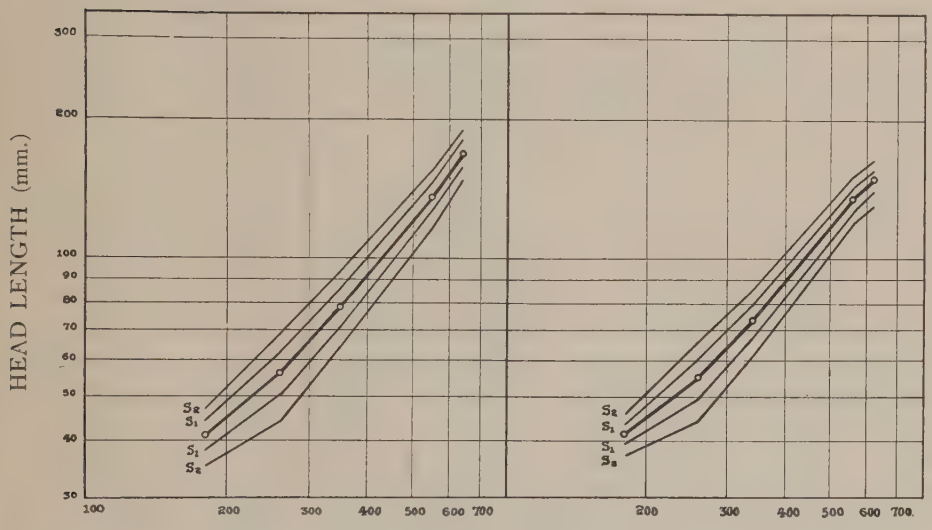

Fig. 2. Males STANDARD LENGTH Fig. 3. Females

FIGURE 2. Growth of the head-length character in male Kamloops trout (for details see page 365).
FIGURE 3. Growth of the head-length character in female Kamloops trout (for details see page 365).

The data are not sufficient to indicate very definitely the relation between the setting in of sexual maturity and the size at which the change from negative to positive heterogony occurs, but there is reason to believe that there is a close correspondence. The male trout in the sample over 40 cm. in length (SL) were divided into two groups, spawners (kelts) and non-spawners (immature and

maturing fish). The indices calculated for these two groups showed that the mature fish had much higher values. Day (1887) remarks that "after breeding, the kelts are recognizable by low lanky bodies and long heads . . . . . in the male the head is longer than the female."

It has also long been known that small (young) trout have relatively larger heads than larger (older) but immature specimens of the same species growing under similar conditions. Day (1887), for instance, remarks that *S. salar* when young has a comparatively large head, but few definite quantitative studies of the change have been made.

If the head-length character is considered throughout the whole life-history of the fish there are at least three trends in its curve of growth. Jenkinson (1912), as a result of a large number of measurements of young rainbow trout, has described the first trend and shows that the head-length increases in proportion to the length of the body in the period following hatching, e.g. from 19.40 per cent at a length of 1.84 cm. to 24.67 per cent at a length of 3.58 cm. Neither the present study nor that of Jenkinson indicate definitely at what size the second trend begins, i.e. when the change from positive to negative heterogony takes place. It undoubtedly varies with the conditions, such as temperature and food supply, and there is probably no difference between males and females. It is a common observation in hatcheries that where the diet is restricted or inadequate the fry or fingerlings have relatively larger heads and poorly developed bodies. This study shows, however, that at a length of 15 cm. the negative tendency has definitely begun. In the case of the Kamloops trout of Kootenay lake the change in the rate of growth of the head from positive to negative heterogony is probably the reflection of an increased growth tendency in the posterior part of the body and may be the result of a more nutritious diet. The kind and amount of food at different stages in growth, as Dymond (1931) suggests, is a possible critical factor in British Columbia lakes affecting the production of trout. Dahl (1910) and Parrot (1932) describe the inflection of the growth curve in *Salmo*, showing an upward trend at one, two or three years of age in certain types. The third trend begins at the onset of sexual maturity when the head commences to grow in length at a more rapid rate than the rest of the body. Because trout do not all mature at the same age, there is a great deal of variability in the size at which positive heterogony begins. The change is more evident in some males at a smaller size than it is in females. The males continue to show a greater positive heterogony than the females throughout the large-size groups. Spawners tend to have larger relative head-length values than non-spawners, and it is more marked in males than females. There is some evidence to suggest that if it were possible to make a seriatim set of measurements on one individual throughout its whole life-history there would be a series of minor fluctuations in the relative proportions of head-length and body, but the changes discussed and described herein would show the major trends.

The phenomenon of positive heterogony in the larger-size groups is probably not generally found among fishes. Hart (1931), for instance, shows that the head-length in *Coregonus clupeaformis* continued to decrease in relation to the length of the body. Positive heterogony of the head in adult fish seems to be a

characteristic feature of many species of the subgenus *Salmoninae* of the family *Salmonidae* of Regan.

The question remains as to what parts of the head are affected by the changes in growth rate at different stages and to what extent the depth and width of the head take part in the general change.

Length of snout. In any description of salmonine fishes, attention is usually drawn to the conspicuous growth of the snout in mature individuals. An examination of this character shows that it is an important contributing factor to the head-length dimension. Figure 4 shows that the Sn, unlike the HL and SnO, is relatively small in small fish, but the Sl′ increase progressively as the size increases. The values of *k*, table III, show negative heterogony for the females in *A*, but in the males there is isogonous growth. In *B* both males and females show positive heterogony, but it is more strongly marked in males than females. The values of *k* for the Sn in *B* are higher than for any other head character.

If the HL is divided into pre-ocular and post-ocular sections by subtracting the Sn mean-values from the HL mean-values for each size group, as shown by table IV, it will be seen that the post-ocular section displays isogonous growth and that the positive heterogony of the HL of the larger fish is due mainly to the increase in the pre-ocular (Sn) rate of growth. The post-ocular section, however, proceeds from a relatively high SL′ in group II to a lower SL′ in group III. The pre-ocular section (Sn), on the other hand, proceeds from relatively low SL′ in groups II and III to gradually increasing values in groups IV-VII. The spawning males have relatively longer snouts than the non-spawners.

TABLE IV. Showing the SL′ and mean-values (M) for the post-ocular section of the head-length character (HL) in the different size groups.

	Males		Females	
	(M)	(SL′) %	(M)	(SL′) %
Group II	32.0	18.0	30.8	18.0
III	42.8	16.6	42.3	16.3
IV	57.4	16.5	54.9	16.3
VI	90.4	16.5	93.4	16.6
VII	108.0	16.9	102.3	16.3

Length of maxillary process. The length of the maxillary process corresponds very closely to the length of the snout in its growth characteristics. The maxillary process displays negative heterogony in the groups of small fish, as the values of *k* for *A* in table III show; in *B* there is evidence of marked positive heterogony ranking next to that of Sn. The SL′ follow the HL characteristics. Figure 5 shows that the SL′ for the maxillary process decrease from group II to group III, but rise from group III to group VII in both sexes. The dotted line in this chart represents the SL′ of (Sn+E). The distance between this line and the heavy central tendency line indicates the extent to which the SL′ of the maxillary extend beyond the SL′ of (Sn+E). This treatment provides a measure of the extent to which the maxillary process projects backward beyond the

eye. As figure 5 shows, there is a gradually increasing backward extension of the maxillary process beyond the eye in larger-size groups in both sexes. The use of this character for taxonomic differentiation, therefore, requires caution.

It is interesting to note in connection with the backward extension of the maxillary process and the marked growth of the snout that the greatest positive heterogony of all the characters is displayed by these two structures in the head region whose growth is not hampered by surrounding parts in at least one direction. The lower jaw, though not studied in the present paper, is similar and displays a marked elongation keeping pace with the snout.

Depth of head. The head-depth proportion follows the same trends as the head-length proportion in the various size groups. The HD is relatively greater

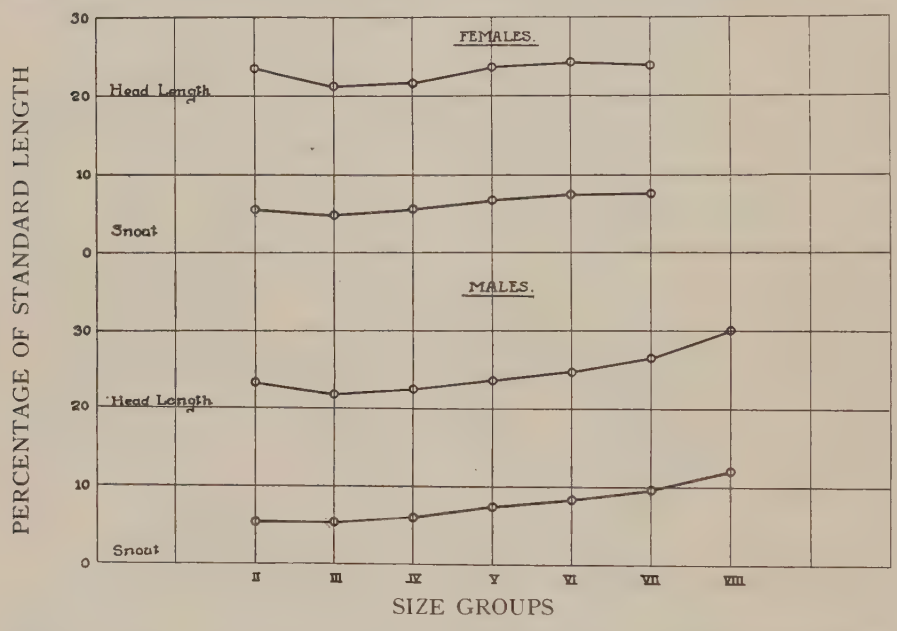

FIGURE 4. Length of the head and snout in male and female Kamloops trout expressed as a percentage of the standard length for the different size groups.

in group II than group III; that is, it decreases proportionately with the growth of the fish for a time. At a certain size corresponding to that at which the relative growth in the HL increases there is a similar increase in HD. With the exception of group II the SL′ are greater in the case of males than in females. The values of k are shown in table III and correspond closely to those for HL.

The positive heterogony of the head length dimension was accounted for by an increase in the growth rate of the pre-ocular section. Figure 6 shows the SL′ for two other depth dimensions beside that of the head, namely, body depth (BD) and caudal peduncle depth (CPD). All three of these characters show a progressive increase in the larger-size groups, both in males and females. Since this character (HD) describes the dorso-ventral dimension of the post-ocular region it will be seen that the growth rate of this area in large fish is greater in the dorso-

ventral direction than it is in the antero-posterior one. This reaction appears to be correlated with the changes in depth taking place in the posterior part of the body.

The differential growth of the length and depth dimensions of the head in the post-ocular region probably affects the shape of the various opercular bones, and consequently suggests caution in the use of the shape of these bones as a criterion for taxonomic differentiation.

Width of interorbital. The interorbital dimension may be taken as a character describing the width of the head. The general trend of the SL′ shows very little change from group II to group IV. The values of k for A in table III indicate that in the small fish the interorbital is undergoing isogonous growth. It is interesting to note that while the length and depth dimensions of the head are growing at a slower rate than the body, the width is growing at the same rate as the body. From group IV to group VI, however, the width dimension is involved in the general display of positive heterogony as the k-values for B, table III, show. Hart (1931) shows that the interorbital of *Coregonus clupeaformis* increased in relative proportion with increase in size, although positive heterogony is not characteristic of other structures in the head region of this species.

Regan (1914) suggests that the size and shape of the bones in the interorbital region, namely the mesethmoid and the frontal bones, are characters upon which the genera *Oncorhynchus* and *Salmo* in the Pacific region may be distinctly separated from the genus *Salmo* in the Atlantic area. In view of the differential growth rate herein described for the interorbital region such a conclusion does not seem warranted unless specimens of the same size, sex and degree of maturity are compared.

Diameter of eye. The diameter of the eye may be considered separately from the other head characters. It is different from the others in that the eye dimension is relatively higher in groups II and III and becomes progressively lower from groups IV to VII. Table III shows that the eye displays negative heterogony in both A and B, and that the negative tendency is greater in females than it is in males. Day (1887) remarks that the eye is comparatively much smaller in adult than young fish. Jenkinson (1912) shows that the relative proportion of the eye is high just after hatching, 7.9 per cent at a length of 1.84 cm.; it subsequently displays a slight decrease, being 7.4 per cent at 3.19 cm. In the Kootenay lake Kamloops trout the SL′ of the eye diameter decreases from 5.5 per cent at a length of 17.8 cm. to 3.5 per cent at a length of 62 cm.

TRUNK AND TAIL PROPORTIONS

Position of dorsal and ventral fins. The position of the dorsal and ventral fins as indicated by SnD and SnV is fairly constant. Table V gives the values of k for A and B. In the former both SnD and SnV have a slight tendency toward negative heterogony and in the latter both characters have a slight tendency toward positive heterogony. These differences are in all probability bound up with the changes which take place in the head-length dimension.

TABLE V. Values of k for the trunk and tail dimensions describing the slope of two segments of the central tendency lines in the logarithmic charts.

	A		B	
	Group II to III		Group IV to VII	
Character	Males	Females	Males	Females
SnD	0.95	0.97	1.1	1.1
SnV	0.94	0.94	1.1	1.1
BD	0.97	0.93	1.2	1.1
BW	0.89	0.91	1.2	1.2
CPL	1.1	1.0	0.88	0.92
CPD	1.1	1.0	1.2	1.1

Depth and width of body. All of the data indicate that the depth and width of the body increase in the larger-size groups both in males and females. The reduced data showed that the SL′ for males are higher than the SL′ for females

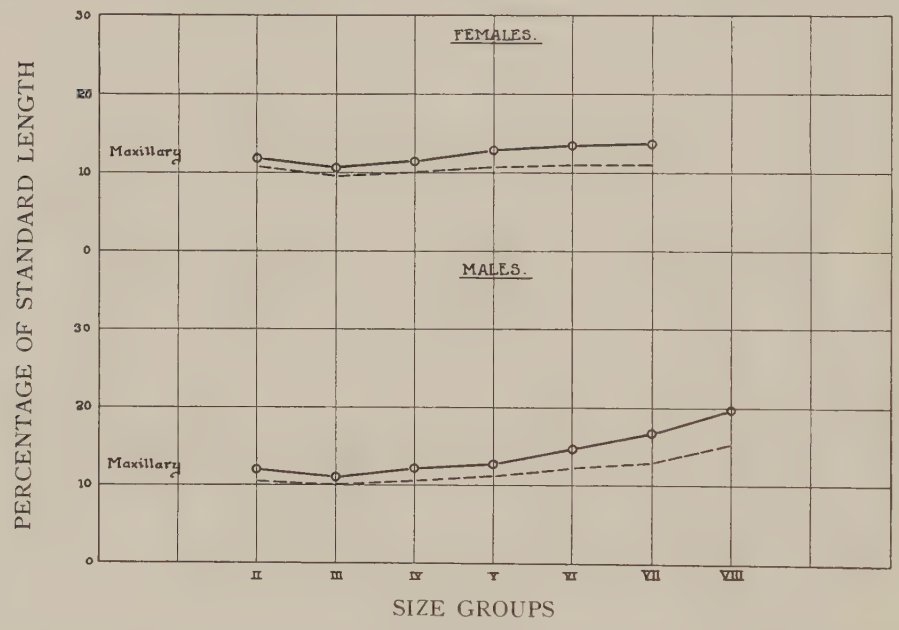

FIGURE 5. Length of the maxillary process in male and female Kamloops trout expressed as a percentage of the standard length for the different size groups. The dotted line shows the standard length index of the snout plus eye-diameter distance and affords a measure of the distance that the maxillary process projects beyond the eye.

in regard to both depth and width. The values of k, table V, show a slight tendency toward negative heterogony in A and positive heterogony in B. Under the discussion of the HL it was suggested that the negative heterogony of the HL between groups II and III was due to a faster development of the posterior section of the body. The data in table V show that the depth and width dimensions are also not growing as fast as the length of the body. In other words, between groups II and III the body is undergoing extension in length at a faster rate than extension in depth or width, and the HL data suggest that this growth is confined to the trunk and tail regions. From groups IV to VII the depth and

width of the body grow at a faster rate than the standard length. This growth is undoubtedly correlated in part with the increase in the size of the reproductive organs, but at a size of about 35 cm. these trout change to a more nutritious type of diet in the form of land-locked sockeye salmon (*Oncorhynchus nerka kennerlyi*), which may cause the differences observed.

Length of caudal peduncle. The length of the caudal peduncle was found to be relatively greater in the small fish than in the larger ones. The CPL grows at approximately the same rate as the body in the smaller-size groups. The value of k, table V, show that in A the males have a slightly higher value than the females, but the growth is practically isogonous. In B, on the other hand, the CPL shows negative heterogony and the condition is more marked in males than females. It is useful to compare this character with the HL in studying the growth of the body parts which are collectively involved in the standard length. The standard length may be considered as made up of the length dimensions of the head, trunk and tail regions. It has already been shown that in the early stages (in A) the HL is growing at a slower rate than the trunk and tail, but later (in B) the head grows at a faster rate. The CPL, however, grows at first (in A) at the same rate as the body, which means at a faster rate than HL; later (in B) it grows at a slower rate than the whole body.

By subtracting the length of the caudal peduncle and the length of the head (HL) from the standard length measurement it is possible to obtain an estimate of the length of the trunk region. The mean values and the standard length indices for this character are shown in table VI. In both males and females the

TABLE VI. Showing the SL′ and mean-values (M) for the length of the trunk region, SL−(HL+CPL), in the different size groups.

	Males		Females	
	(M)	(SL′) %	(M)	(SL′) %
Group II	106.7	60.1	102.3	59.8
III	156.8	61.0	159.9	61.8
IV	210.4	60.7	208.7	61.7
VI	321.9	58.9	334.2	59.7
VII	369.4	57.9	375.3	60.3

SL′ of the trunk have slightly higher values in groups III and IV, indicating an increased growth tendency in this region at the immature adult stage. It was shown above that the depth and width of the trunk (BD and BW) grow at a slower rate than the whole body from group II to group III; the net effect of which is to produce a longer, more slender or terete fish at the immature adult stage. Obviously the amount of food, age and size at maturity may affect such characters and these considerations point to the necessity for care when using the shape or appearance of trout in taxonomy.

Depth of caudal peduncle. The depth of the caudal peduncle shows isogonous growth in A, but a tendency toward positive heterogony in B. The CPD is probably correlated with HD and BD in this respect. The tendency toward positive heterogony is more marked in males than in females.

FIN PROPORTIONS

Height of dorsal fin. The DHt was found to decrease from group II to group III in SL′ of both sexes. From group III to group VII there is very little fluctuation. The values of k in table VII show negative heterogony in A, but an isogonous condition in B. The difference between males and females in this character is slight. The greater SL′ for the dorsal fin in group II seems to indicate that a high dorsal fin is a juvenile characteristic.

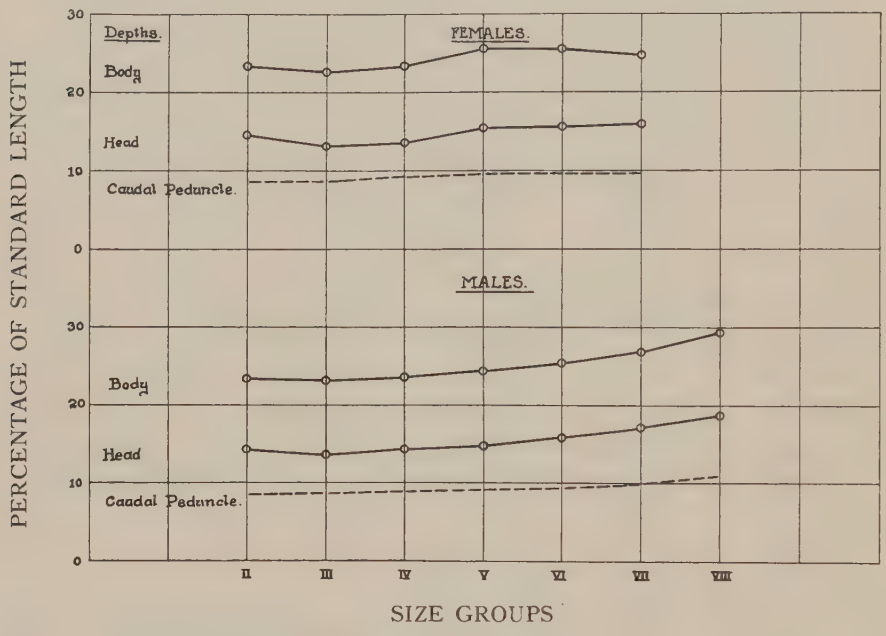

FIGURE 6. Depth of the head, body and caudal peduncle in male and female Kamloops trout expressed as a percentage of the standard length for the different size groups.

TABLE VII. Values of k for the fin dimensions describing the slope of two segments of the central tendency lines in the logarithmic charts.

	A		B	
	Group II to III		Group IV to VII	
Character	Males	Females	Males	Females
DHt	0.75	0.72	1.0	0.96
DBa	0.87	0.81	1.1	1.1
AHt	0.98	0.88	0.95	0.92
ABa	0.88	0.93	1.2	1.1
PL	1.0	0.93	1.0	0.88
VL	1.0	0.97	1.0	0.95
CL	1.1	0.93	0.92	0.94

Length of base of dorsal fin. The DBa follows the DHt very closely. There is evidence of negative heterogony in A and positive heterogony in B. The positive heterogony in the DBa of larger fish is in distinct contrast with the

growth of the length of the trunk which displays negative heterogony in the groups of larger fish. There is no difference between males and females.

Height of anal fin. The AHt is quite similar to the DHt but there is a slight tendency toward negative heterogony in *A* and *B* in both sexes. There is practically no difference in the SL′ of males and females.

Length of base of anal fin. This character resembles the DBa. *A* shows negative heterogony and *B* positive heterogony. It is interesting that the base of the anal fin should be found to grow at a faster rate than the body when the CPL shows negative heterogony. This change in the growth rate may be affected by the adjacent change in BD. There is some reason to believe, however, that the increase in relative size of both the DBa and ABa is associated with the onset of maturity and may be the result of a thickening of the bony and epidermal structures of the fin.

Length of pectoral fin. The salient feature of this characterization is the high SL′ for group IV in both sexes. The females in *B* show negative heterogony in contrast to the isogonous condition of the males; possibly the form changes in the two sexes induce this difference. Day (1887) states that the pectoral fin is relatively longer in trout at an age of three or four years. Day (1887) and Agassiz (in Day 1887) have suggested that the length of the pectoral fin is affected by the habitat, thus trout in rapid streams have longer pectoral fins. It is usually assumed that the pectoral fin is associated with the maintenance of balance so that growth changes affecting different parts of the body may bring about a disturbed balance and thus modify the PL, but there are no precise data on this point.

Length of ventral fin. The VL is fairly constant throughout all size groups and in both sexes. The growth rate is practically isogonous, being slightly less in females.

Length of caudal fin. The SL′ of the caudal fin decrease from group to group in a fairly regular manner in both sexes. The amount of forking was once considered to be of value in diagnosing the various species of trout, but Day (1887) has shown that the proportions of the fin change with size and age.

FORM-CHANGE IN KAMLOOPS TROUT

From the foregoing analysis of the body characters or continuous variables, of the Kamloops trout of Kootenay lake, it is possible to draw a comprehensive picture of the change in form which accompanies the change in size.

Comparison of males and females

It has been shown in the previous discussion that the males differ from the females in several characters, and so it is expedient to describe them separately.

The juvenile male and female Kamloops trout of Kootenay lake show little difference in the relative size of the various characters. The immature male and female trout are also quite similar. Owing to the tendency for males to mature a year earlier than females, characters such as the head-length and depth show a greater degree of variability in males. A few males with relatively longer heads thus raise the SL′ mean values in group III.

The mature male and female trout, however, show a great deal of difference

in several characters. The males have a relatively longer and deeper head, longer snout and maxillary, and a wider and deeper body.

Form-change in male Kamloops trout.

Comparison A (group II and group III). The juvenile male Kamloops trout of Kootenay lake are characterized by a relatively long, deep head; large eyes; short snout; narrow interorbital; short maxillary reaching as far as the vertical from the posterior margin of the eye, a terete (narrow and shallow) body; long, shallow caudal peduncle; high dorsal fin and long caudal fin.

The immature adult male Kamloops trout of Kootenay lake have a relatively shorter, less deep head; smaller eyes; shorter maxillary; narrower body; longer caudal peduncle; lower dorsal fin, with a shorter base.

Between these two stages the snout, the interorbital, the body depth, the height of the anal fin, the length of the pectoral fin and the length of the ventral fin grow at practically the same rate as the body (SL). The length and depth of the caudal peduncle and the length of the caudal fin grow at a slightly faster rate than the body. The length of the head, the maxillary, the depth of the head, the diameter of the eye, the distance from the snout to the dorsal and ventral fins, the body width, the height of the dorsal fin and the length of the bases of both dorsal and anal fins grow at a slower rate than the body.

Comparison B (group IV and group VII). The mature adult male Kamloops trout, as compared with immature individuals have a relatively longer, deeper head; smaller eye; much longer snout; wider interorbital; longer maxillary; wider and deeper body; shorter but deeper caudal peduncle.

Between the two stages, group IV and group VII, the height of the dorsal fin, the length of the pectoral fin and the length of the ventral fin grow at the same rate as the body. The length and depth of the head, the snout, the maxillary, the interorbital, the distance from the snout to the dorsal and ventral fins, the body width and depth, the depth of the caudal peduncle, the length of the bases of the dorsal and anal fins grow at a faster rate then the body. The diameter of the eye, the length of the caudal peduncle, the height of the anal fin and the length of the caudal fin grow at a slower rate than the body.

Form-change in Female Kamloops Trout

Comaprison A (group II and group III). The juvenile female Kamloops trout of Kootenay lake are characterized by a relatively long, deep head; large eyes, short snout and maxillary, terete body; long, shallow caudal peduncle; high dorsal fin and long caudal fin.

The immature adult female Kamloops trout of Kootenay lake have a relatively shorter, less deep head; smaller eyes; smaller snout and maxillary; more terete body; lower dorsal fin with a shorter base; lower anal fin, with a shorter base; and shorter pectoral, ventral and caudal fins.

Between these two stages the interorbital, the snout-to-dorsal distance, the caudal peduncle length and depth and the length of the ventral fin grow at approximately the same rate as the body. No character except the length of the trunk ($k=1.2$) was found to be growing at a faster rate than the body. The length and depth of the head, the snout and maxillary, the eye, the snout-to-ventral distance, the body depth and width, the height of the dorsal and anal

fins, the length of the bases of the dorsal and anal fins, the length of the pectoral fin and the length of the caudal fin all grow at a slower rate than the body.

Comparison B (group IV and group VII). The mature female Kamloops trout of Kootenay lake, as compared with immature indivduals, have a relatively longer, deeper head; smaller eyes; longer snout and maxillary; wider, deeper body; and shorter, deeper caudal peduncle.

Between these two stages the height of the dorsal fin grows at the same rate as the body. The length of the head, depth of the head, snout, maxillary and interorbital, the distance from the snout to the dorsal and ventral fins, the width and depth of the body, the depth of the caudal peduncle and the length of the bases of both dorsal and anal fins grow at a faster rate than the body. The eye, the length of the caudal peduncle, the height of the anal fin and the length of the pectoral ventral and caudal fins grow at a slower rate than the body.

Discontinuous Variables

Unlike the continuous variables, which are used for characterising body dimensions, the discontinuous variables are not affected by changes in size, nor is there reason to suspect differences due to sex. A comparison of the values in table VIII, where the sexes have been segregated, reveals that there is no signi-

Table VIII. The reduced data for the number of gill rakers, branchiostegals, dorsal and anal fin rays of the Kamloops trout of Kootenay lake arranged according to size and sex.

	Sex	Number of specimens	Mean value	Standard deviation
Gill rakers				
Groups II, III, IV	Males	60	19.2	1.2
	Females	92	19.2	1.0
Groups V to VIII (incl.)	Males	29	19.7	0.89
	Females	33	19.7	0.78
Branchiostegals				
Groups II, III, IV	Males	60	11.6	0.56
	Females	90	11.6	0.66
Groups V to VIII (incl.)	Males	30	11.4	0.58
	Females	33	11.2	0.54
Dorsal fin rays				
Groups II, III, IV	Males	60	11.1	0.58
	Females	93	11.3	0.48
Groups V to VIII (incl.)	Males	30	10.7	0.58
	Females	33	10.8	0.66
Anal fin rays				
Groups I, III, IV	Males	60	10.9	0.54
	Females	92	11.0	0.45
Groups V to VIII (incl.)	Males	30	10.7	0.53
	Females	33	10.8	0.61

ficant difference between the means (M) in the four characters, namely, gill rakers, branchiostegals, dorsal and anal fin rays. There is a slight difference correlated with size in the data for the number of gill rakers. The difference between the M-values for small fish and the M-values for large fish is 0.5 for both sexes. The males have a standard error of the difference of 0.22 and the females have a standard error of the difference of 0.17. The difference in both cases is more than twice the standard error of the difference and hence the significance may be considered problematical. There is the possibility that extremely small processes could be overlooked in making the count on the arch of a small fish, which would account for the lower mean value; on the other hand, as Foerster and Pritchard (1935) indicate, extra gill rakers may grow as the fish increases in size.

The stability of these characters under different environmental conditions should be determined by experiments as has been done for the number of scale rows. (Mottley 1934.)

CONCLUSION

In the preceding sections it has been shown that many of the body proportions of Kamloops trout, such as the head-length and depth, snout- and maxillary-length, diameter of the eye, interorbital-width, body-depth and width, caudal-peduncle-length and depth and the fin-lengths, change with the growth of the fish, and are different in the two sexes. In view of such changes in characters to which importance is sometimes attached in the taxonomic study of fishes, one is forced to the position that these characters must be used with caution if entirely unwarranted conclusions are to be avoided. For instance, the fact that two fishes, or two groups of fishes, have heads of entirely different relative lengths, may be of no taxonomic significance in itself. Such differences may be due to a wide variety of causes affecting the growth of the fish.

Comparisons should be made if possible between specimens of the same size, age, sex and degree of maturity. This, however, is not always possible, as, for instance, in the comparison of dwarfed and large forms. Studies like the present one should prove of value in such cases in providing an evaluation of the difference observed between various characters.

It is not possible to apply the results of this study directly to other fishes since different groups have different evolutionary histories, different genetic potentialities and are affected in different ways with growth and the development of the secondary sexual characters. Probably the general conclusions can be applied with a reasonable degree of assurance to closely related races and species such as the forms of rainbow trout or cutthroat trout.

This study, however, shows the necessity of investigating the effect of such factors as growth, sex and the environment on the characters on which reliance is being placed in taxonomic studies. Fishes being organisms of indeterminate growth, characters, such as those investigated here, are probably more subject to variation from environmental causes of modifications and ontogenetic reactions than is the case with warm-blooded vertebrates which are characterized by a more fixed adult size.

The extent of variation also probably varies from group to group among the fishes. The group *Salmonidae* to which the trout belong, is usually regarded as being more subject to modification with the environment than most groups. This may be due to the wide tolerance which many of the *Salmonidae* exhibit toward extreme conditions; thus trout, *Salmo*, are found from sea level to altitudes of over 5,000 feet (over 1500 m.) in British Columbia, and they are known to live within a broad range of latitude. The so-called "plasticity" of the trout may thus be the reflection of a wide range of environmental conditions impinging on a highly tolerant biological group. However, in the absence of precise analyses the extent to which this may be true is not known.

ACKNOWLEDGMENTS

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Age determinations of Salmon Parr by effect of Rate of Growth on Body Proportions.

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ABSTRACT

Rapidly growing fish (as shown by scales) have short heads and small eyes. Plotting eye diameter against length of fish places, with few exceptions, each year class in a separate zone. On this basis, age may be determined.

During the summer of 1931, salmon parr were collected from a number of streams in Cumberland county, N.S., and it was noticed that parr from certain streams had relatively large eyes. The collections of parr were preserved in formalin solution and later measurements were made of total length, head-length and eye-diameter. These measurements, from which the graphs of figure 1 for head-length and figure 2 for eye-diameter have been plotted, revealed

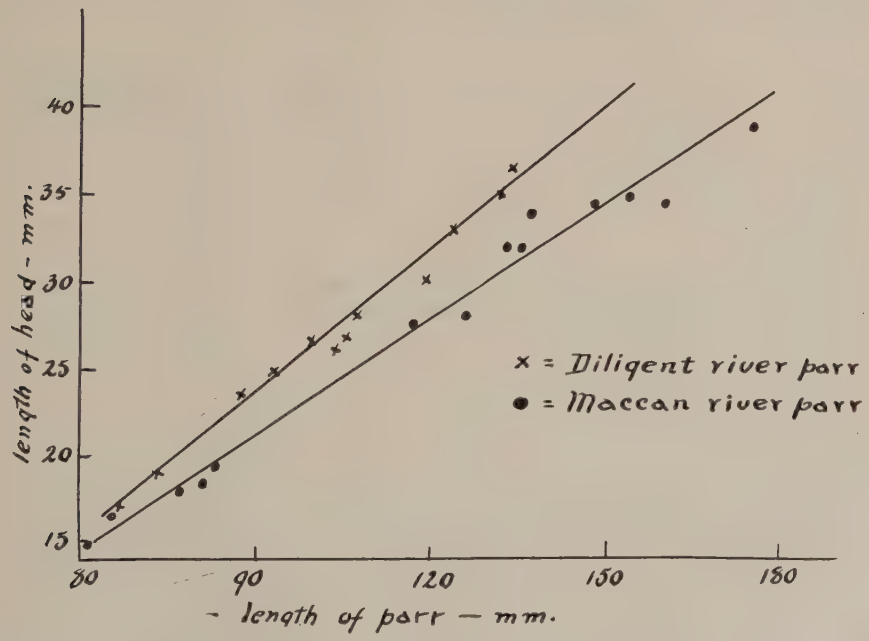

Figure 1. Total length of parr (nose to centre caudal fin) vs. length of head. This graph shows that the Diligent river parr have heads relatively larger than the Maccan river parr.

the fact that parr from Diligent river have relatively larger heads and also relatively larger eyes than parr from Maccan river. Parr collected from other local streams were mostly intermediate in relative head-length and eye diameter, between the extremes found in Diligent and Maccan rivers. An exception to this was found in parr taken from the brackish waters of the estuary of Apple river. These parr had relatively smaller heads and and eyes than any parr found in fresh water. (See Annual Report of the Biological Board, 1933, p. 42, 1934).

The factor, total length divided by head-length, for Maccan river parr varies from 4.00 to 4.77 whereas the same factor for Diligent river parr varies from 3.67 to 4.00. The greatest difference in the factors for the parr of the two rivers is obtained for the largest parr from the two streams.

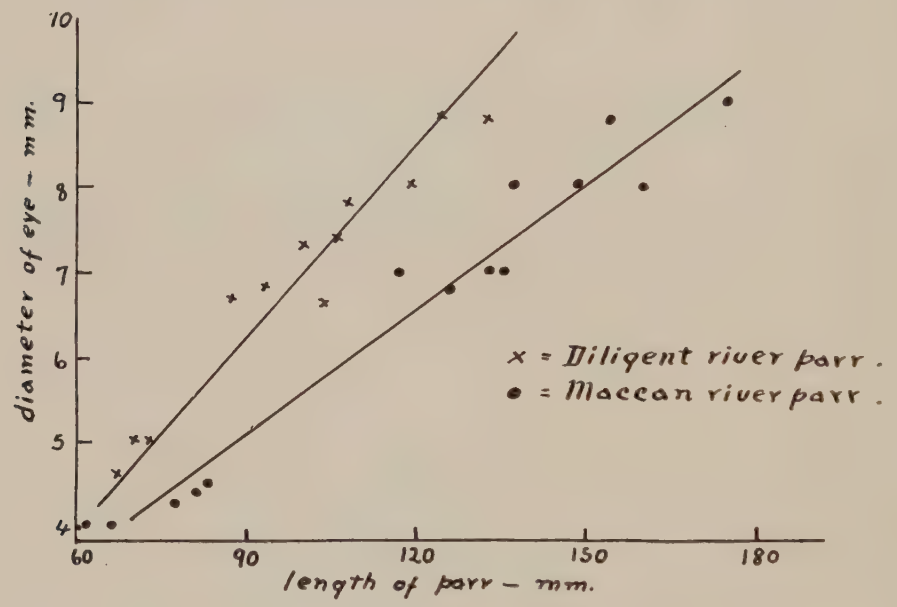

FIGURE 2. Total length of parr vs. diameter of eye. This graph shows that the Diligent river parr have relatively larger eyes than the Maccan river parr.

The factor, total length divided by eye-diameter, varies from 15.2 to 20.0 for Maccan river and from 13.4 to 15.7 for Diligent river parr. Here again, the greatest difference is found between the factors for the largest parr from the two streams. In figures 1 and 2 it will be seen that the separate graphs for the two streams diverge, going from small to large fish, in both the head-length (figure 1) and in the eye-diameter (figure 2), indicating that the difference develops with growth.

After making these comparisons we found on reading the scales of these fishes that the parr with the larger eyes were those which had made a slower growth. Consequently the following summer, during the month of June, we

made other collections of parr from various streams and plotted the data for length against those for eye-diameter, as shown in figure 3. At this time the age of each parr was determined from scale reading and it was found that, with scarcely any overlapping, data for parr of different ages fell within oblique zones, which have been indicated in the figure. In this graph all the data for parr from Diligent river, the stream where growth is slowest, lie near the broken line D-R.

In determining ages from scale readings we have found that scales from certain parr (or smolts) do not show winter check-marks distinctly. When eye measurements have been plotted against total lengths and a graph made similar to the one accompanying this paper, it has been determined that when these

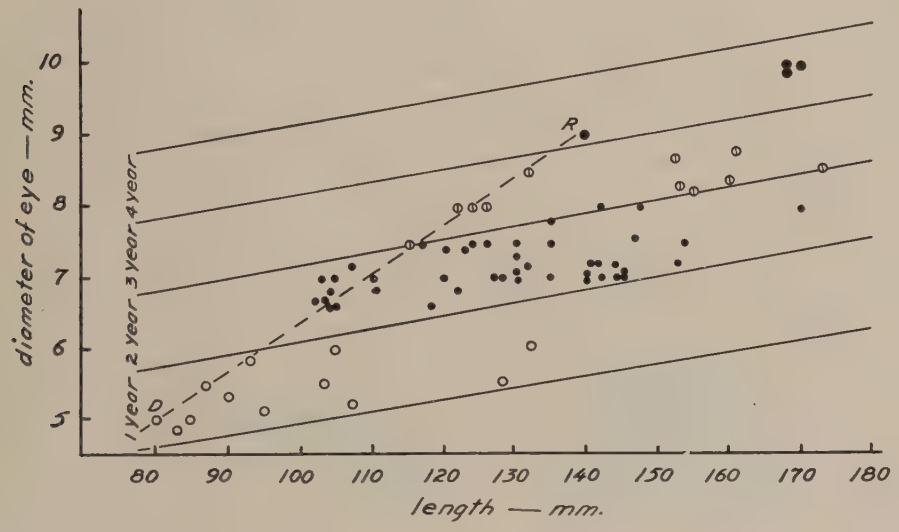

FIGURE 3. Eye-diameter vs. total length (to centre of caudal fin). Circles show data for 1-winter parr; small dots 2-winter parr; circle with bar 3-winter parr, and large dots 4-winter parr. Note that the data for the various year-classes fall into oblique zones. Data for Diligent river parr lie along line D-R.

do not fall within the proper "year zone", a further examination of the scales may reveal that a winter check mark has been overlooked in scale reading.

After examining a number of specimens taking particular note of the *relative* size of the eye it will be found that with few exceptions the ages of parr may be adjudged without scale reading or actual measurements.

Figure 4 consists of sketches (drawn to the same scale) of two parr (11 cm.) from different rivers. The upper fish, having a larger eye, may at once be judged to be a year older than the lower fish. This is confirmed on looking at the scales, that for the upper (A) showing three seasons' growth as compared with that for the lower (B) showing only two seasons' growth.

We have noted that both the brook trout and eels in common with young

salmon from certain streams have relatively large eyes and our observations would indicate that this method of age calculation is probably applicable to other fishes. We suggest that those using the "length-group" method of age determination might get more definite year-class groups by dealing separately with those fish having relatively larger eyes.

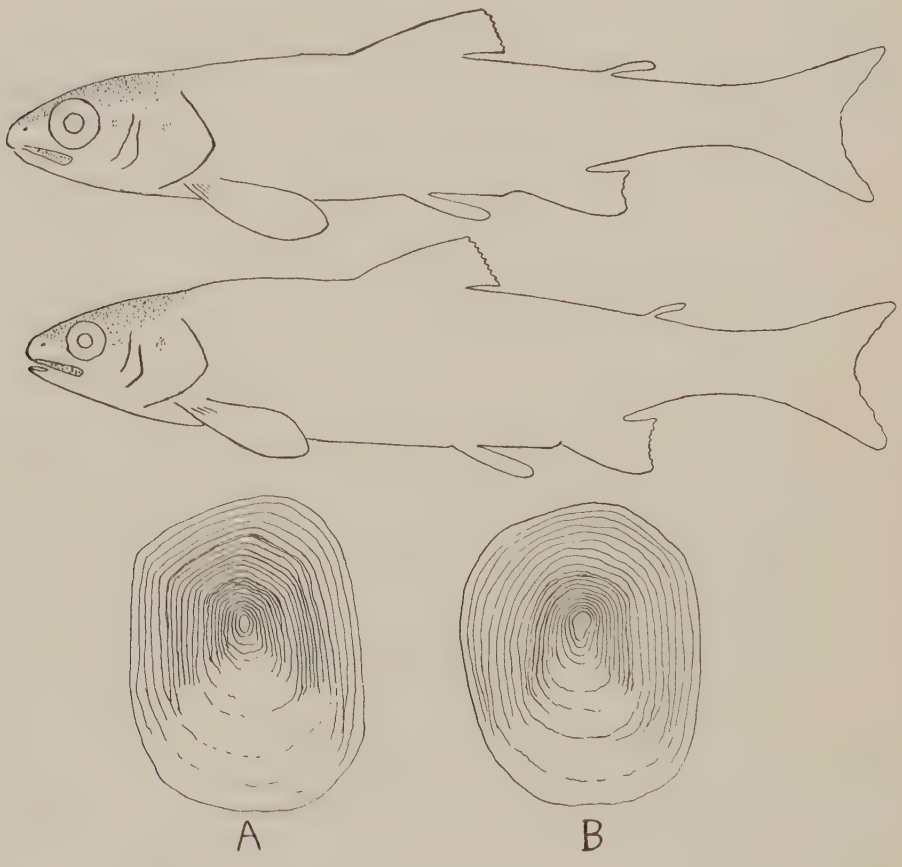

FIGURE 4. Two parr, each eleven cm. long, drawn to scale. The upper parr is a 2-winter parr. The lower one a 1-winter parr. Note that the older parr has a relatively large eye.

Factors influencing the Upstream spawning Migration of the Pink Salmon, *Oncorhynchus gorbuscha* (Walbaum)

By A. L. Pritchard
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ABSTRACT

From data collected at McClinton creek, Masset inlet, British Columbia, as a result of a comprehensive programme of investigation on the pink salmon, *Oncorhynchus gorbuscha*, a positive significant mathematical correlation is demonstrated between numbers of fish migrating from the sea to the stream each day and both the maximum daily water height in the creek and the daily rainfall in the area. A positive significant correlation also exists between the maximum water height and the rainfall. From available records no co-variation between numbers of migrants and changes in temperature can be shown.

For many years interest has been taken in the factors which influence anadromous fish in their movements from the sea into fresh-water streams and also in those which induce individuals already in fresh water to move up to the spawning areas. The influence of flood waters on schools of salmon near a river mouth has been recognized qualitatively by almost every investigator who has studied the life history of such forms. Huntsman (1934) and Calderwood (1930) in discussing the Atlantic salmon, genus *Salmo*, briefly sum up the situation. The former states:

"There is definite evidence that the water issuing from a river into the sea is of great importance in determining the entrance of salmon into that river. How the effect is exerted is not very clear. Whether it be through temperature, oxygen content, or some peculiar characteristic of the river water, the important thing is that the salmon seem to be guided by it to the river mouth, . . ."

The latter reports:

"Just as a rise in river draws fish from the sea, so a rise induces fish already in fresh water to 'run'. When a flood is high, however, they tend to seek easy water and to wait till the weight of the flood is over before again continuing their ascent."

Likewise for the Pacific salmon, genus *Oncorhynchus*, Chamberlain (1907) records:

"The influence of flood waters on schools near a river's mouth may be due in part to an increased temperature as well as to an augmented volume. It is well known that in dry seasons, when the streams are low, even though a sufficient depth for a practicable ascent may remain, schools tarry in the bays much longer than in rainy seasons. But as this is marked only in the case of small streams the main factor must be volume or quantity of water."

As a part of a comprehensive programme to obtain information on the efficiency of natural propagation for the pink salmon, *O. gorbuscha*, the Biological

Board of Canada for some years has operated a counting fence at McClinton creek, Masset inlet, British Columbia. The opportunity was thus presented to check closely the spawning runs of the species under consideration. It was possible also to collect records pertaining to the height of the water and the temperature of the creek, and the amount of rainfall. These data, herein presented, clearly demonstrate a definite mathematical relationship between numbers of upstream migrants, the water height and the rainfall.

The life of the pink salmon may be divided arbitrarily and roughly into two phases, viz., "the fresh-water" and "the marine". The former includes the period from the time when the adult salmon enter the stream in the autumn until their progeny, approximately 3.8 centimetres (one and one-half inches) in length, leave the river during the next spring. Of the latter or "marine" phase which covers the remainder of the life cycle, little is known since, peculiarly enough, once the fry reach salt water, they disappear almost entirely. Only on rare occasions are young ones taken. Two years later the adults are encountered in large schools on their way to the spawning grounds.

In contrast to the sockeye and spring salmon, these fish, when depositing their sexual products, frequent chiefly the small coastwise streams or the lower tributaries of the larger river systems, which in the majority of cases do not have lakes at their sources. They do not penetrate far inland. The result of this behaviour is that the eggs are usually deposited in streams which on account of their physical characteristics are subject to sudden rises and quick drops in water height. Such streams are typified by McClinton creek where the detailed observations were carried out.

As a general rule adult pink salmon appear at the head of McClinton bay off the mouth of the creek late in the month of August in every even-numbered year. At the time of arrival, the individuals are in firm condition and silvery, with the secondary sexual characters of the males, viz., elongated curved snout and hump on the back, showing very little development. It is a matter of common observation that, if the weather is dry, most of the salmon will remain in salt water at the head of the bay for an extended period, only scattered individuals entering the creek at high tide or on the first of the ebb. If before rainfall occurs, the fish become "ripe", *i.e.*, attain a condition in which the eggs and sperms are fully developed, loose, and ready to be discharged, they will attempt to ascend the river no matter how little water there may be. Under such circumstances the stimulus of the "ripening" gonads appears to be of prime importance. In the McClinton creek area, however, where the annual rainfall amounts to more than two hundred and fifty centimetres (one hundred inches), drought conditions are uncommon especially in the autumn when the salmon runs take place. Usually, therefore, upstream migration begins whenever freshets occur regardless of the state of sexual development.

METHODS

The counting fence, the apparatus used to allow examination of the spawning migrants, was similar to the ordinary hatchery rack employed throughout the province for egg collections with the exception of slight modifications for handling,

storage, and withstanding the pressure of the heavy current which is common in McClinton creek. Figure 1 illustrates the general features of this structure.

Constructed on a solid plank platform, three and two-thirds metres (twelve feet) in width and sealed on both upstream and downstream sides with sheet piling, the fence proper consisted of square wooden pickets (A) set sufficiently close together to prevent the passage of any fish through them. The creek was thus blocked from bank to bank to ascending migrants except at two points where funnels (B) allowed the fish to penetrate and become impounded in the retaining traps (C). In practice the pink salmon, finding their upstream passage obstructed by the fence, worked their way along it until they discovered the openings of the funnels which lead to the traps, and proceeded through. From the traps they were then dipped out, counted, "sexed", and otherwise examined.

FIGURE 1. Counting fence at McClinton creek, Masset inlet, B.C.

Water height in the creek was read from a gauge which was merely a long strip of galvanized tin, divided and numbered in tenths of feet (3.0 centimetres). This was nailed to the cribbing at the edge of the fence in such a way that the bottom was level with the bed of the stream and the strip itself was perpendicular.

The rainfall was collected in a standard gauge supplied for the purpose by the Meteorological Service, Dominion of Canada Department of Marine, and measured in the accompanying glass cylinder which was graduated in units equivalent to hundredths of inches (one-fortieth of a centimetre) of rainfall. Temperatures were taken with an ordinary centigrade thermometer.

RESULTS

In figures 2 and 3 are plotted frequency diagrams for the numbers of fish entering the traps each day, the maximum daily water height, and the daily

rainfall, during the periods of the pink salmon runs in 1932 and 1934. Across the top of each diagram are recorded graphically the temperatures of the water taken each day at approximately 9.00 a.m. and 6.00 p.m.

Correlation between numbers of adult spawning migrants and both rainfall and water height at the weir is suggested by even a superficial examination of the graphs. The extent of this relationship is indicated by the following correlation coefficients calculated from the original data:

Coefficients of correlation
between
Daily Counts of Migrants
(Number of males + number of females)
and

1932	Aug. 25-Oct. 2	Maximum daily water height	0.72∓0.052
		Daily rainfall	0.85∓0.030
1934	Aug. 18-Oct. 11	Maximum daily water height	0.25∓0.085
		Daily rainfall	0.49∓0.069
	Aug. 18-Oct. 3	Maximum daily water height	0.51∓0.073
		Daily rainfall	0.74∓0.044

In every case with the exception of the water height for the full period of the run in 1934 (.25∓.085), the coefficients are positive and significant being more than six times their own probable error. The reason for the one apparent contradiction is evident. In 1934 after October 3 the supply of fish off the mouth of the creek was exhausted and thus even though the water height did rise, migrants did not appear in any numbers. For a similar reason the rainfall-migrant correlation for the complete run in that year is also lower than that for the period from the beginning to October 3. It may therefore be definitely concluded that the numbers of migrants increase with increase in rainfall or a rise in water height in the creek.

It is interesting to note that in 1934 when much larger numbers of salmon were schooled off the mouth of the creek (total run—155,183), a small rise in the river brought in much larger numbers than a rise of a similar size in 1932 when a smaller run occurred (15,600).

As would be expected rainfall and water height in the stream are co-variables. The coefficients of correlation, .71∓.054 in 1932, and .61∓.057 in 1934, show that the interrelationship is very high. As a matter of fact qualitative observations have demonstrated this to be the case. Approximately two hours after a rain the water in the creek will invariably take on a brownish colour and commence to rise. After a more or less extended dry period, which usually occurs in July, when the snow has all been melted off the mountains from which the creek takes its source, as much as 1.9 centimetres (three-quarters of an inch) of rain within one day is required to raise the water to any noticeable degree. Once the surrounding land has been "saturated", a condition which usually exists in autumn when the salmon runs appear, very much smaller amounts suffice to cause a freshet.

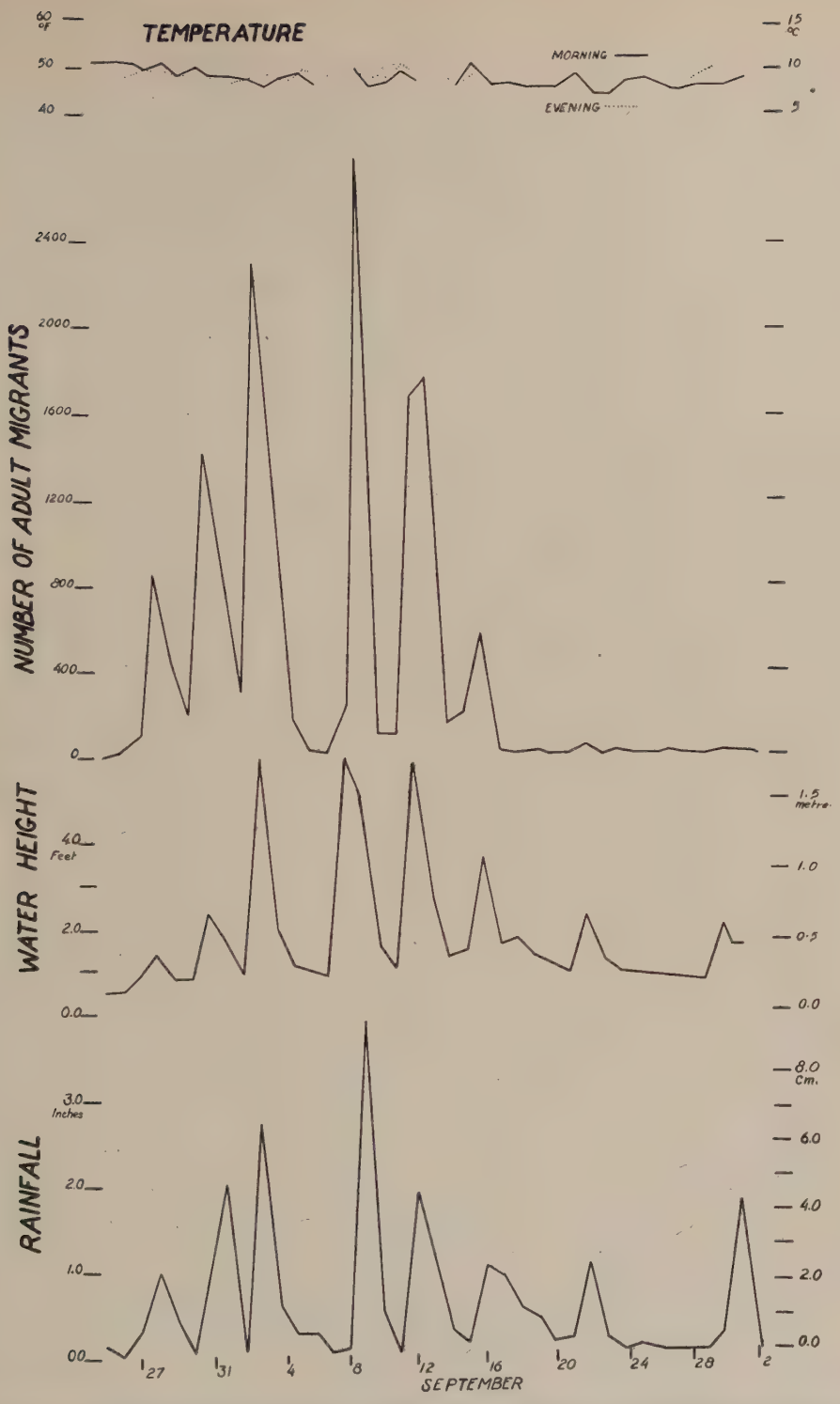

FIGURE 2. Showing for the spawning run of 1932 the numbers of adult pink salmon reaching the weir at McClinton creek daily, the maximum daily water height at this weir, the daily rainfall, and the water temperatures taken at approximately 9.00 a.m. and 6.00 p.m. each day.

There is one peculiarity of the runs which is not brought out by the graphs or the mathematical expression of the relationship between the various factors recorded above. In extreme freshets caused by a daily rainfall of five centi-

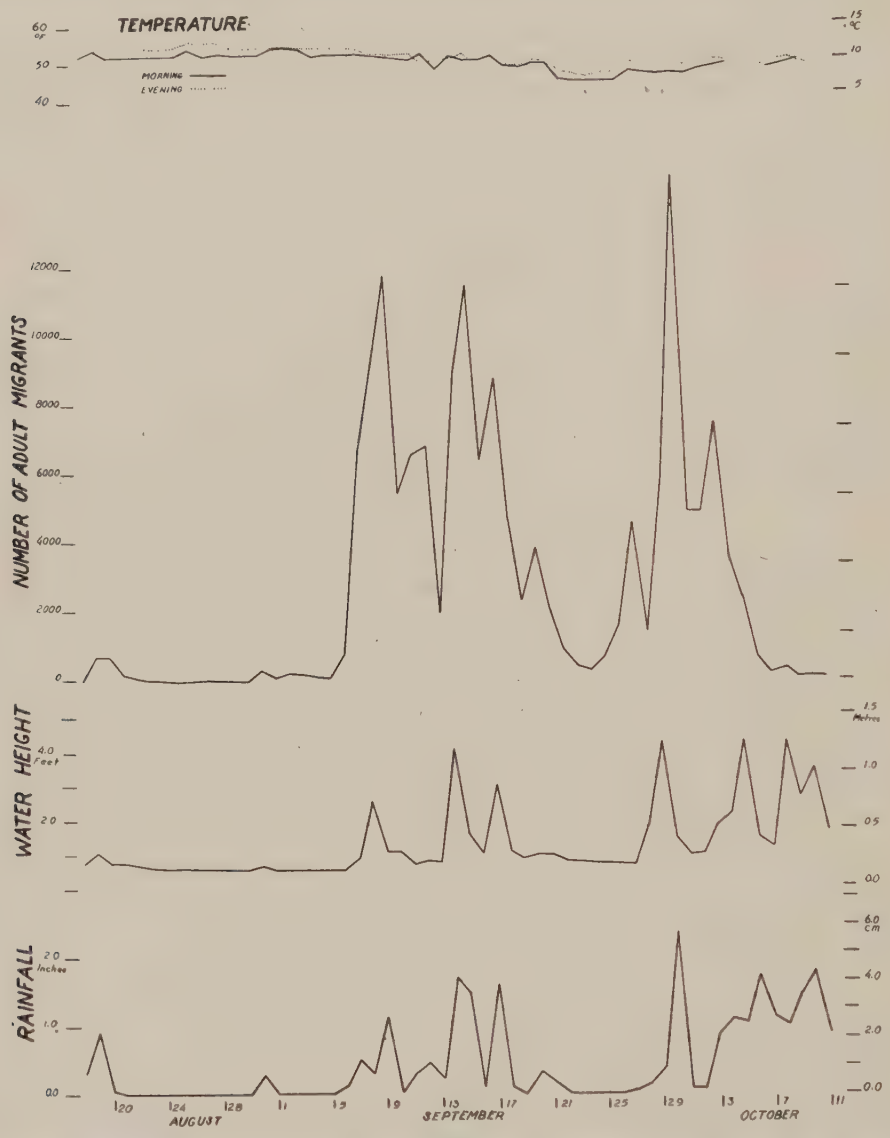

FIGURE 3. Showing for the spawning run of 1934 the numbers of adult pink salmon reaching the weir at McClinton creek daily, the maximum daily water height at this weir, the daily rainfall, and the water temperatures taken at approximately 9.00 a.m. and 6.00 p.m. each day.

metres (two inches) or more, the numbers of migrants drop off at the peak of the flood. At McClinton creek when the height of the water reaches 1.1 metres (3.6 feet), the current apparently is becoming too strong and the numbers

of fish reaching the weir begin to drop off. At water levels exceeding 1.3 metres (4.4 feet) all remain in the back-eddies out of the main stream. As the level when falling again approaches 1.1 metres (3.6 feet), upstream ascent recommences. It is pertinent in this connection to note that for chum and coho salmon which are usually larger individuals, the height of the water which forces retreat to the back-eddies out of the current is considerably higher. These observations suggest for each species an optimum current at which largest numbers migrate upstream and a maximum stream flow above which none can migrate.

These qualitative data would appear to be in direct contradiction to the quantitative information which has been presented since the graphs show largest numbers migrating on the largest freshets. After heavy rains sufficient to cause floods of these proportions, however, the water drops fairly quickly to approximately one and one-fifth metres (four feet) and rather slowly thereafter. In view of the large amount of water distributed throughout the whole drainage basin, the period of the run-off is much more extended than that resulting from a sudden limited rainfall. The freshet will thus have an effect on the migrants over a longer period and give rise to a greater run in the twenty-four hours, the period of time which is the unit in the abscissae of the graphs.

The temperature records at hand include readings taken at approximately 9.00 a.m. and 6.00 p.m. daily and on some days six or eight readings throughout the twenty-four fours. As far as it has been possible to discover from this more or less fragmentary information there is no sign of a relationship between increase in upstream migrants and changes in temperature.

SUMMARY

The number of adult pink salmon migrating daily from the sea to the spawning areas in McClinton creek, Masset inlet, British Columbia, is positively and very significantly correlated with both the maximum daily water height in the stream and the daily rainfall in the region. This correlation is evident in spite of the fact that extreme freshet conditions may reduce or even arrest migration. A significant positive correlation also exists between the two variables, maximum daily water height and daily rainfall. From available data no definite effect of changes in temperature in producing a run can be demonstrated.

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The Homing of Salmon in Apple River, N.S.

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ABSTRACT

Salmon from the East branch marked as smolts in 1934 returned as grilse in the fall of 1935, entering only the East branch up to spawning time. After October 22 more entered the West than the East branch. Female salmon tagged as adults gave evidence of remaining each in a particular "home" pool. After spawning some females dropped down to tidal pools in early November and later reascended the stream. Male salmon tagged as adults left their "home" pools, roaming up and down and even going through tidal water to the other branch; yet males came back the second year to the same pool in which they were taken (in one case repeatedly) in the first year.

That anadromous fishes, and particularly salmon, return to their parent stream after their sojourn in the sea has been popularly accepted, but to many of those engaged in fisheries research this idea is still regarded as a theory. The concept of this theory is that fishes have a homing instinct and are not only able to return to their home region from a distance but are able to select the particular stream from which they migrated. The reason for scepticism regarding this theory is that there are many records of marked fishes being taken hundreds of miles away from their home stream and at times even in other streams. Moreover in the accounts of the salmon markings there appears to be no record that salmon which have returned to their home streams have ever been any distance away from the mouths of their respective streams. If, when they become river-mature, their parent stream is the nearest stream, then the fact that they return to that stream is in no sense conclusive that they have selected that stream. Yet there is considerable evidence favouring the parent stream theory. The fact that there are differences in the range of sizes and average sizes of the salmon which enter different streams or, as Gilbert (1919) has pointed out for the sockeye salmon, even in different branches or different spawning areas of the same stream, would seem to indicate that under natural conditions the various streams or branches have distinct populations and that the fish of each succeeding generation return to the place where they were hatched. Rich and Holmes (1928) who have carried out experiments on the Chinook salmon of the Pacific have stated as follows. "The so called parent-stream theory is now substantiated by such a wealth of evidence that it seems nearly superfluous to state that none of the salmon marked on the Columbia have been recovered in any other river system." Further, in speaking of certain returns of adults from smolts marked in a small tributary of the Columbia river,

they have said: "This stream is so extremely small that it is difficult to see how the salmon could find it at all, and yet 82 of the fish marked here were recaptured here as adults, while only 4 were taken in other spawning tributaries. This is the most definite evidence known to us of the validity of the home-stream theory as applied to tributaries." More recent experiments in British Columbia (Clemens, 1935, p. 26) have shown that of 3,285 returns from a marking in McClinton creek, 2,950 were retaken in their parent stream. Only seven were reported from areas outside the Queen Charlotte islands. On the other hand evidence of straying also comes from a McClinton creek (Queen Charlotte islands) marking (Pritchard, 1934, p. 94), in which none of the marked fish were taken in either the stream from which the eggs came or the stream where the marked fish were liberated, but fish bearing the marking used were recaptured in the Fraser river over 600 miles (1000 km.) south.

Tagging of Atlantic salmon smolts by Alm (1931) in the Indals and Angerman rivers of Sweden has shown that the Atlantic salmon may go hundreds of miles from the stream from which they migrated as smolts. A number of the fish tagged in these streams were recaptured in the Southern Baltic over six hundred miles (1000 km.) from the stream in which they were marked. However, six fish tagged in the Angerman were retaken in that stream and six fish tagged in the Indals were recaptured in the Indals. None of the fish was reported from any other river. The mouths of these two streams are more than thirty miles (50 km.) apart and there is thus a possibility that the fish which returned had never been away from the influence of their respective streams. The same question may be raised in regard to the smolt markings in the Tay river of Scotland. Of the smolts tagged in that stream, all recaptures have been made in the Tay. Calderwood (1908, p. 82) states regarding the Tay: "The great volume of water—reputed to be the largest in the British Isles—may make itself felt for a very considerable distance seawards and so give a guide to Tay fish in the sea." It is therefore possible, even if considered improbable, that the Tay fish mature at sea without coming within the influence of any other river.

In making these suggestions regarding the valuable experiments above, we wish merely to draw attention to the circumstantial nature of the evidence from which conclusions have been drawn.

Recently we have obtained returns from salmon tagging experiments at Apple river, which have yielded evidence of homing as well as of straying of salmon.

Apple river is a small stream of Cumberland county, Nova Scotia, emptying into Chignecto bay, which is a part of the bay of Fundy. The main river is wholly tidal and at low tide it is merely a stream of approximately fresh water flowing for nearly three miles (4.5 km.) through the tidal flats. There is only one deep pool in this part of the stream and that is situated near the mouth at a place called "The Narrows". This pool is locally known as the "Salmon Hole", for, as the salmon drop back out of the estuary with the last of the ebbing tide, many of them collect in this pool. There are two tributaries flowing into Apple river, the East and the West branches, and approximately the lower mile (1.6 km.) of each of these branches is also tidal. During high tide, which in this region

may be 28 feet (8.5 m.) higher than low tide, these two branches discharge separately two miles (3 km.) from each other into tidal water. In our papers (White 1933, 1934a, 1934b) concerning the salmon investigations in this area we have referred to the two streams as East Apple river and West Apple river or merely as the East and West branches. In the accompanying map (figure 1) the extent of the tidal flats is shown by the stippled areas. The fresh water parts of the two branches are very similar in flow, temperature and other physical characters. Both branches originally contained salmon, but some sixty years ago a dam was erected at the head of tide on the East branch and the run of salmon into that stream was stopped. Although the dam had been out for ten years previous to our arrival there in 1931, there had been no known run of adult salmon into the fresh water of that branch. During our investigations

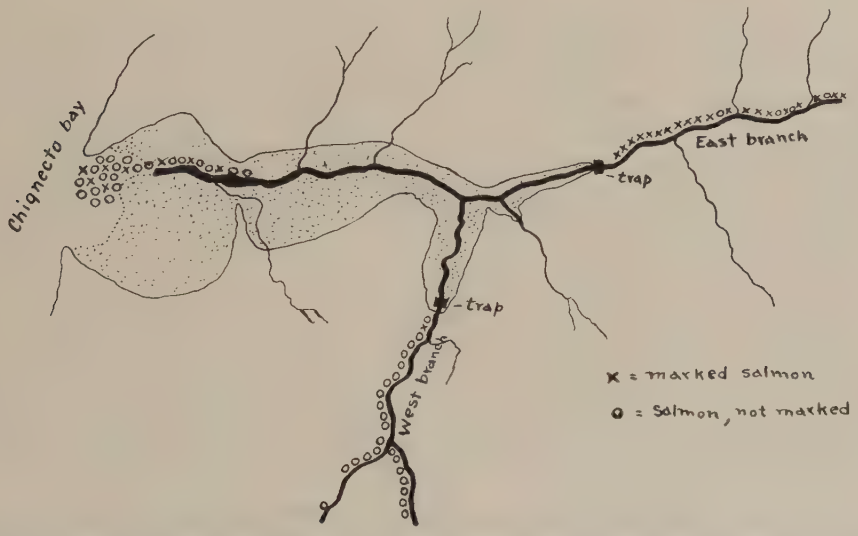

FIGURE 2. Map of Apple river showing the main stream and lower part of the two branches. The extent of the tidal flats is indicated by the stippled areas. The known position of marked (x) and unmarked (o) grilse is shown where they were first in the estuary and again in the branches where they were after migration.

there in 1931 we found that salmon came in from the sea with the tides to the heads of the estuaries of both branches, but dropped back to the outer estuaries or to the sea with the ebbing tide. This behaviour became more pronounced in the late summer when a few salmon began to appear in the West branch in the estuarial pools and also in the stream above tide water. By mid-September the numbers of salmon observed at high tide in both branches increased, and by this time many salmon were ascending the West branch; yet throughout the fall no salmon were found either in its estuarial pools (*i.e.*, at low tide) or ascending the East branch. The tides rushing into the estuary carried many of the salmon past the mouth of the West branch, but they evidently continued to go in and out until finding themselves in the West branch estuary they ascended that

branch. Throughout the summer of 1931 we made many seine hauls above tidal waters in both branches. In the West branch we took large numbers of salmon in various stages as well as many trout (*Salvelinus fontinalis*), but during all our seining on the East branch we took trout only. In the spring of 1932 we found numerous kelts in the pools of the West branch, but none were found in the East branch.

During late June and early July large numbers of newly-emerged salmon fry could be observed on all the rapids of the West branch, but although we searched several miles of the most suitable salmon spawning areas in the East branch we were unable to find any salmon fry. However, after the fry planting, later described, salmon fry were readily found over the entire region where the planting was made.

MARKING OF SMOLTS

On July 15, 1932, 25,000 salmon fry, from the Restigouche river of New Brunswick, were planted along a mile (1.6 km.) of the East branch above the head of tide, and this planting was under observation during the summers of 1932 and 1933. Most, if not all, of the survivors from this planting migrated to sea during May and June of 1934. The smolts in this migration were captured by placing a rack and trap across the stream at the head of tide water. The adipose fin of each smolt was completely removed by shaving it off with a razor and then the fish was released below the trap. 3,252 smolts were thus marked. At the time of this migration thousands of smolts were descending the West branch, but none of these were marked.

Since the local fish return almost wholly as grilse after one full year at sea, it was expected that there would be a return in the fall of 1935 of grilse from these smolt markings. During that summer we were carrying on investigations on the Margaree river, but had left instructions with certain residents of Apple River village to notify us as soon as salmon began to appear in the river.

In early August, we received word that salmon having the adipose fin missing were being taken in poachers' nets in the river near its mouth, particularly in the "Salmon Hole". We returned to Apple river on August 20 and we were able to verify the information which we had received concerning marked salmon. By interviewing a number of the fishermen who were operating the gill nets we were later able to make an estimate of the number of fish taken. The water in the rivers had been exceedingly low throughout the summer, the lowest known in this region for many years. By August 29, a trap for catching ascending salmon had been installed on the East branch, and by September 11 a similar trap had been completed on the West branch. The type of trap used consisted of a rack barrier having one inch (2.5 cm.) spaces and a rectangular pound with a V-shaped lead opening into it.

On August 29 there was a rise in the stream level; on August 30 a single marked grilse entered the East branch trap and on August 31 another marked grilse was taken. The water dropped very rapidly and no more fish entered the trap until September 16. There was a heavy rain on September 14 causing the river levels to rise about two feet (60 cm.). The river water became very

red and carried considerable floating trash. One salmon was taken in the East branch trap on September 16, but on the 17th, when the water was subsiding and clearing, 9 salmon entered this trap. Of these ten salmon, one was a second-spawner and nine were marked grilse. Between September 11 and 16 six unmarked grilse were taken in the West branch trap. On the night of the 16th during the high water the pound of this trap was smashed by a large drift-log which allowed the salmon to escape upstream, so that there is no record for this trap on September 17. However the trap was repaired at once and on September 18 thirteen unmarked grilse were taken. Up to and including October 22, 88 marked grilse were taken in the East branch trap, while during the same period on the West branch 164 grilse were taken, none of which were marked fish.

Up to this point in the experiment the marked fish coming in from the outer estuary had entered only the fresh water of the branch from which they had migrated. According to our previous observations on the behaviour of salmon here, both marked and unmarked fish would be carried by the flood tide far up the estuaries of both branches, but with the ebbing tide those fish, which found themselves not within the influence of the waters of their home stream, would go out with the ebbing tide, while those ready to ascend, and finding themselves within the influence of their parent branch, would remain in the small pools of the estuarial part of that stream and then ascend into the fresh water during the night. This was a common method of ascent, but fish may have ascended the streams all the way from the lower estuary during ebb-tide.

After October 22, when most of the fish entering the river were ripe or nearly ripe, there was no definite evidence of homing among the marked fish. Of ten marked fish taken after this date, all of which were ripe and with sea-lice still on them, six were captured in the West branch while four were taken in the East branch. However, the East branch trap was broken on October 24 and some fish escaped. The explanation of the straying of marked fish into the West branch would appear to be that, these fish being ripe, it was the spawning urge rather than their homing tendency which determined their behaviour.

On the map in figure 1 we have indicated the known positions of the marked and unmarked salmon both before and after passing through the traps. The concentration of fish in the outer estuary is shown where they were being taken by the fishermen and again after their migration into the fresh water of the two branches.

In figure 2 we have represented by vertical columns the numbers of grilse entering each of the two branches in each three-day period. The solid black in these columns shows which were marked grilse. The contrast of the runs into the two branches is easily recognized. The occasional unmarked grilse entering the East branch may have been from smolts missed in the marking of 1934 or stray fish either from the West branch or from some distant stream.

This experiment demonstrates that Atlantic salmon have some means of selecting the stream in which they were reared. But it does not indicate that they possess any ability to return from a distance to their home stream. We have as yet no evidence that any of the marked salmon have ever been beyond the influence of the water from Apple river.

TAGGING OF ADULT SALMON

Movements in the River

In 1931, salmon of the spawning run into the West branch were seined from time to time from three pools, namely, Bridge pool, at the head of tide, Elderkin pool about half a mile above (0.8 km.), and Long pool nearly half a mile (0.8 km.) still further up stream.

These salmon were weighed, measured and tagged with metal tags attached to the dorsal fin. 100 salmon in all were tagged and during these operations between September 15 and November 23 a number of the same fish were recaptured. A considerable number of the tagged fish were killed by poachers, but those which escaped yielded information concerning the behaviour of the salmon while in the stream.

Figure 2. The numbers of grilse taken in successive three-day periods in the traps on each branch. The upper is that for the East branch and the lower is that for the West branch. Marked fish are indicated by solid black.

Two salmon, a male and female, taken first in the Bridge pool in September were later retaken in Elderkin pool, and two others taken in Elderkin pool were later retaken in Long pool. These early captures of clean fish are examples of fish making their up-stream migration. However, when the females had reached certain pools they tended to remain in those pools for a considerable time. We have numerous examples of this behaviour, but records of a few will suffice to demonstrate this. No. 1212, a female weighing 11 lb. 4 oz. (5.1 kg.) was taken in Elderkin pool on September 26, and was retaken from the same pool September 30 and October 7. On November 9 she was retaken as a kelt weighing 8 lb. 8 oz. (3.9 kg.) and was finally retaken in the same pool on November 17. Another fish, no. 1217, also a female, was taken in Elderkin pool six times between September 26 and November 17. This fish weighed 9 lb. 8 oz. (4.3 kg.) but when finally retaken as a kelt, weighed 7 lb. 6 oz. (3.3 kg.)

No. 1226 was taken five times in Elderkin pool. No. 1222, a female grilse, was taken three times from the Long pool, unspawned on September 26 and October 7 and as a kelt on November 11. This behaviour in Elderkin pool is shown on the graphs in figure 4.

After spawning there was much more shifting among the females. This was at first a down-stream movement of many of the fish to the head of tide. In figure 3, the concentration of fish in Bridge pool is shown by the Bridge pool graph. Throughout the early part of the fall only four or five salmon remained in the Bridge pool, but on November 11, 26 female kelts and one male were taken from this pool. Coincident with the concentration in Bridge pool (and

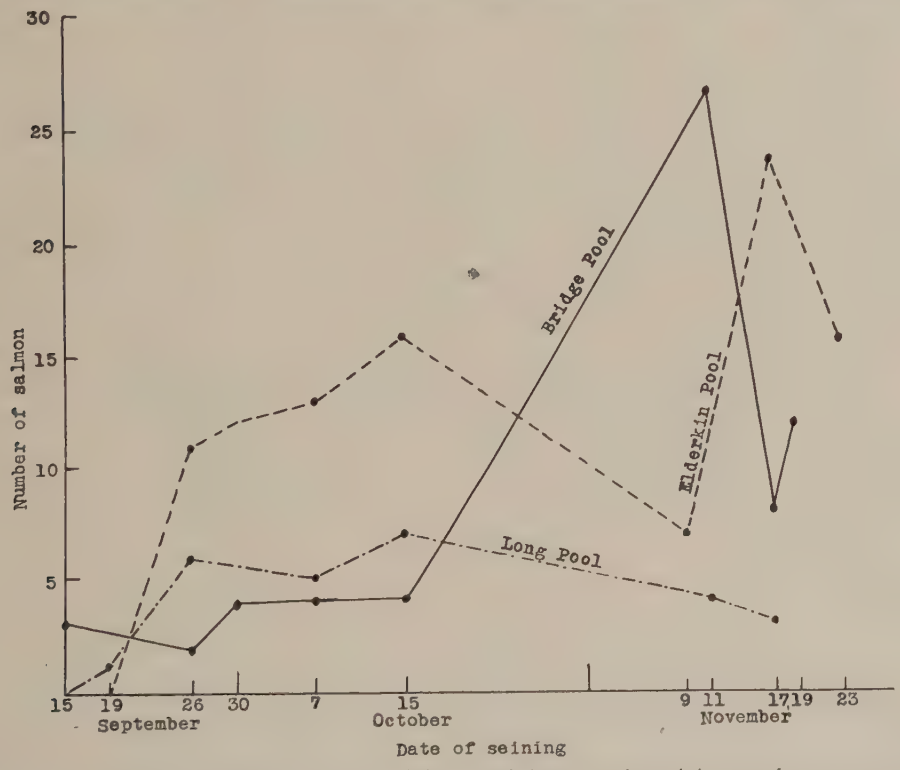

FIGURE 3. Numbers of fish taken in each of three pools in successive seinings to show movements of fish as indicated by changing numbers.

probably also in other pools at the head of tide) there was a decrease in the numbers in Elderkin pool. This is shown in the Elderkin pool graph, in the same figure. There was also a decrease in the number of salmon in Long pool. That the concentration in the lowest pool was in part due to migration down from Elderkin pool was shown by the recapture in Bridge pool of kelts which had previously been staying in Elderkin pool. Conversely on November 19 there was a rise in the number of fish in Elderkin pool and a decrease in Bridge pool and that this was in part due to an upward migration of female kelts was shown by the recapture in Elderkin pool of four kelts which were tagged in

Bridge pool on November 11. On November 23 two other tagged kelts from Bridge pool were retaken in Elderkin pool. These recaptures indicating the movements down stream and back again are shown in figure 4. Another example of up stream migration of a kelt was in the East branch where a female salmon spawned on a rapids below the head of tide and was later taken in a trap upstream. The male which accompanied this female at the time of spawning was also taken but it was only partly spent. There are other records of the upstream migration of kelts.

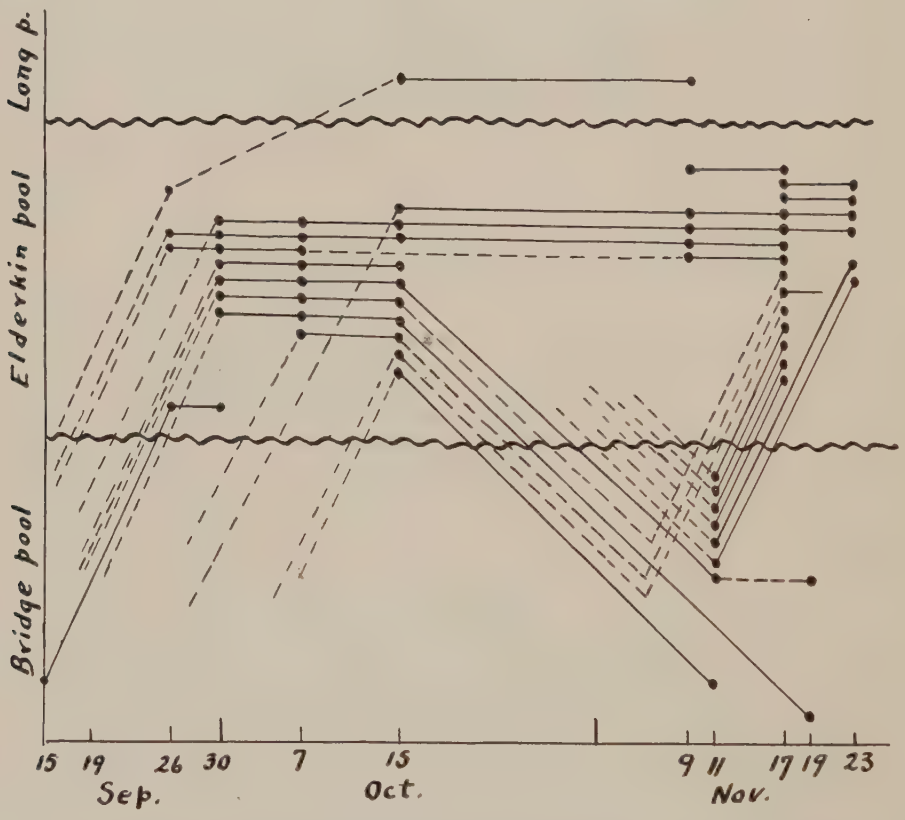

FIGURE 4. Behaviour of recaptured tagged fish related to Elderkin pool. Dots represent actual captures of individual fish. A solid line shows that the fish was taken in successive seinings while broken lines indicate probable behaviour at times when not captured in the seining of the pool. The figure shows a downstream migration of kelts early in November and an upstream migration later.

A large number of kelts have been tagged by the Fish Cultural branch of the Department of Fisheries under the direction of Mr. J. A. Rodd. Kelts tagged in the mouth of the Saint John river in tidal water have been retaken as kelts the following spring far up the river. Although this is suggestive of a behaviour like that of Apple river fish it is possible that these fish may not have been completely stripped by the spawn takers and had migrated upstream to deposit eggs which they still retained. Huntsman (1931, p. 79) in summing

up the various captures of tagged kelts retaken within a month or so after liberation, makes the following statement: "The results indicate that some of the fish, wherever tagged in the tidal water of the river, tend to remain there, going up from the mouth and down from the head." This was the behaviour of Apple river female kelts, but in reascending the river they went upstream above the head of tide. Since most of the kelts of Apple river remain in the stream all winter, many of them staying in Elderkin pool, this migration down stream and up again may have been in search of deep water in which to winter.

Few males were taken in comparison with the number of females, the numbers being 20 males and 80 females, and the behaviour of the males differed from that of the females. Although a number of them were retaken in certain pools they were apparently missing from these pools for periods throughout the fall. No. 1214, a male fish, was first taken in Elderkin pool September 26, was not taken in the seinings of this pool on September 30 and October 7 but was retaken there on October 15. It was not in the seinings there on November 9 and 17 but was recaptured in the hauls on November 23. We have similar records for other males, but most of the males taken were captured but once. All our observations indicate that males cruise up and down the stream during the spawning season. This past fall (1935) a male tagged in the West branch descended this branch after the trap was removed and was retaken up the East branch. Our recaptures of tagged fish show that females have "home" pools, which they may occupy for long periods, but our most outstanding indication of this type of homing is that of two male salmon tagged in Long pool. One of these fish was taken as an unspawned male on October 15, 1931, as a kelt on November 17 and again as a fresh-run fish on October 4, 1932, in each case in the same pool. Another male taken in the Long pool as a fresh-run fish on October 4, 1932, was retaken from the same pool on September 28, 1933, after having spent a summer at sea.

Return from the Sea

In the falls of 1932, 1933 and 1934, that is after the planting of the fry in the East branch of Apple river, salmon entered that branch as they had not been known to do for many years. We have called these "stray" salmon and have advanced the theory that such salmon enter streams where they detect the presence of young salmon from the water flowing from the streams (White, 1934b, p. 260). In 1934 we tagged the salmon entering the East branch and during our trapping of salmon in 1935, seven returns from these taggings were secured. Of these recaptures five returned to the East branch where they had previously spawned, while two which had spawned in the East branch the previous year were retaken in the West branch trap. Although the numbers are too small for definite conclusions, they indicate the tendency of these fish to return to the stream where they had previously spawned and probably spent the winter. The straying of two out of seven into the West branch, however, is a higher percentage of straying into that stream than occurred among the grilse marked as smolts. One other tagged salmon was taken in the estuary in July and another in the bay of Fundy, near Lorneville in the Saint John river

fishing area, a distance of seventy miles (113 km.) away. This latter is our only record of Apple river salmon being taken at any place other than Apple river.

The results of recaptures of adult fish from marked smolts have shown that salmon may consistently return up to the spawning time to their home branch of a river system. Our recaptures of tagged salmon have shown that they tend to return to the branch where they have previously spawned and that this homing tendency may even be to return to a particular pool in the branch.

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Fatness, Digestion and Food of Passamaquoddy Young Herring

By Helen I. Battle, A. G. Huntsman, Anne M. Jeffers, G. W. Jeffers, W. H. Johnson, and N. A. McNairn

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ABSTRACT

Using condition factor as criterion of fatness, investigation confirms the report of those handling them that herring are characteristically fat in each locality of the Passamaquoddy region of southern New Brunswick. Herring feed by an act of capture, moving towards the source of light in doing so. They do not feed in darkness, requiring light about as strong as moonlight. Gastric digestion takes 25½ hours at 6° and 6 and 7 hours at 20°C. in herring 14 to 16 cm. long. Where fattest, herring contain the most food and of the larger kinds. In some localities herring have more food and of special kinds after moonlight nights. Herring are mainly in upper layers of water in summer, and nearer surface when light intensity is low. Correlation between fatness of herring and either the total quantity of food present locally or the local degree of concentration of food in the water is quite imperfect. Good correlation exists between fatness and quantity of food present *near the surface* in the particular locality. In localities where herring have more food after moonlight nights, food organisms are much more abundant near the surface in moonlight than in sunlight. Food organisms are most concentrated in passages and near shoals where thorough mixing of the water occurs. In the passages at the mouth of Passamaquoddy bay, deepwater forms from the gulf of Maine are available at the surface at all times of the day, giving the fattest herring. To exhibit characteristic fatness herring must remain some weeks in the locality.

A general enquiry into local peculiarities of the herring in the Passamaquoddy region of southern New Brunswick has shown that the fishermen are aware of many more or less constant differences between the herring of localities but a few miles distant from each other. These differences are not of such a character as to indicate fish of different origin or of different racial stock. Rather do they tend to show that the herring frequently remain sufficiently long in a given locality to be definitely affected by the peculiar conditions occurring there.

Fishermen state that the fattest herring of the region are taken at Harbour de Loutre, Campobello (figure 1), or in Cobscook bay back of Eastport. Mr. W. H. Lord, of Deer Island, stated that the fattest herring occurred in Cobscook bay, and that they were progressively less fat going to Harbour de Loutre (Campobello), outer Deer island, and the Inner bay. Mr. A. M. A. McLean of Connors Bros., sardine canners of Blacks Harbour, undertook to procure independently from four different men, with long experience in handling herring, estimations of the relative fatness of the herring taken in 35 different localities throughout the region. Five grades were specified,—very fat, quite fat, medium, poor, very poor. Two of the men considered it necessary to add a sixth grade, VERY poor.

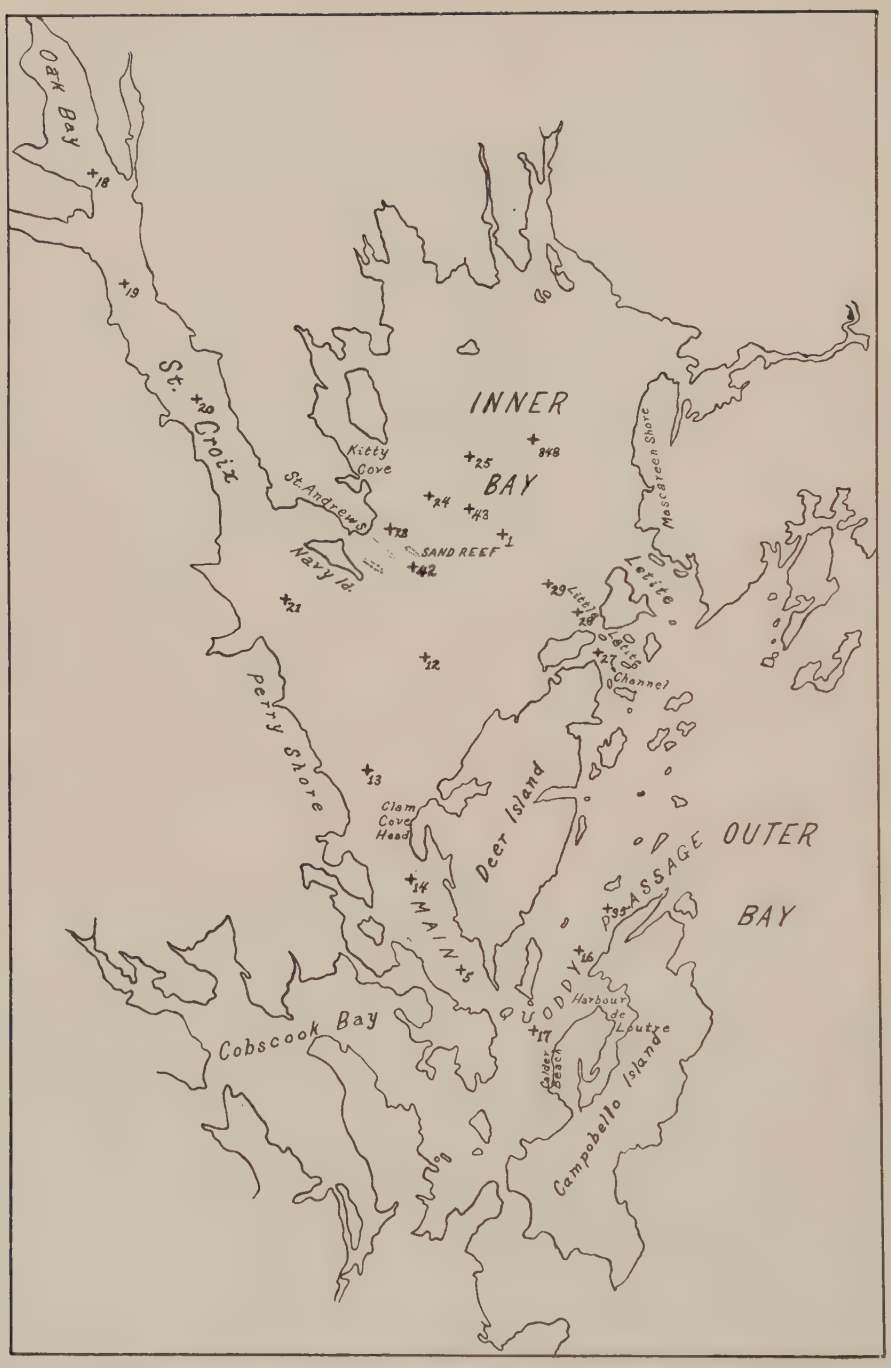

FIGURE 1. Passamaquoddy region, showing numbered stations and localities to which reference is made.

While the independent estimations agreed only for eleven localities, for no locality were there estimations differing by more than one place. The men were Mr. V. H. Bradford, Sr., buyer at the factory, Capt. Wm. Matthews of the schooner "Bernadine", Capt. Ward Hatt of the boat "Alice J.", and Capt. Sydney Thompson of the boat "Alpha".

The combined result is shown in figure 2, the relative fatness of the herring being indicated by the relative thickness of the lens-like marks. It will be seen that the fattest fish occur on the Campobello and United States side of the main passage at the mouth of the Inner bay, and that the fatness diminishes going in

FIGURE 2. Relative fatness in herring of the Passamaquoddy and neighbouring regions, outer bay of Fundy. Thickness of lens-shaped bodies represents gradation in fatness.

every direction from the passage. This order would seem to be of some significance.

So far as we are aware nothing comparable to this has been described. If this condition actually exists, the question at once arises,—what is the explanation? It does not seem to agree with the view that the herring undertakes feeding migrations (McIntosh and Masterman 1897, p. 421; Meek 1916, p. 77) and that herring will be concentrated where their food is abundant (Herdman and Riddell 1913, p. 192) so that they may be located by discovering where their food is.

The condition is rather in harmony with the view that herring are carried by movements of the water as described for this Passamaquoddy region (Hunts-

man 1934) and are fat or lean depending upon the food available to them in the place to which they are carried. Ljungman wrote confidently (1880, p. 197), "when the herrings come in to seek food they will generally go to those waters where they have been accustomed to find food in the greatest abundance." There have been various attempts to establish a relation between the herring and its food, such as in the expedition of the "Holsatia" in 1887 in the Baltic sea (Hensen 1890, p. 103) and in the work of the Lancashire Sea Fisheries Laboratory in the Irish sea (Herdman and Riddell 1913, p. 192). Recent attempts have been those of Savage and Hardy in the North sea off the East Anglian coast, and from the results obtained the former concludes (Savage 1931, p. 53) "there appears to be a good relation between the abundance of planktonic food and the quantity and quality of the herring."

The Passamaquoddy region is one in which there is an exceptionally great concentration of herring. Formerly it was of the spawning herring on the southern side of Grand Manan island at the mouth of the bay of Fundy (Perley 1852, p. 173; Earll 1887, p. 441), but in more recent times the abundance has been of the immature, largely of those in their second year of life, when they are of suitable size for canning as sardines. Their centre of abundance is at the mouth of Passamaquoddy bay, in the "Channel" district, near but definitely distinct from the district where the fattest fish are found (see above). It is with these yearling fish that we are chiefly concerned in this study of fatness.

This condition (if actually existing) of variable and relatively constant local fatness will throw light upon "migration", since to reflect in their fatness the local conditions the herring must remain for a considerable time in the one locality. They are as a matter of fact known to be present in many parts of the region in all months of the year, within the Inner bay as well as outside its mouth and at Grand Manan. Also this very great concentration of yearling herring in the region has been brought to attention as a result of a proposal to place tidal power dams at the focal point of the concentration across the mouths of the Inner bay; and Cobscook bay is actually at the present time in process of being dammed. Light may well be thrown on the as yet unknown causes of this concentration of young herring (Huntsman 1928, p. 30; Graham 1936, p. 122).

It was decided to procure facts during the season of 1933 in order to test this matter of characteristic local fatness and also to discover if possible the reasons for it. Full elucidation of such a complex matter would require much more time than it has been possible to devote to this subject. Considerably more material was studied than could properly be used for final presentation of results. Limitation in material made us finally concentrate attention on a series of four localities in line from Campobello island to Oak bay, and even so the material for two of these is unsatisfactorily small.

Mr. N. A. McNairn examined the herring as to fatness, and Mr. W. H. Johnson as to the food they had eaten. Mrs. A. M. Jeffers studied the relative abundance of the planktonic food (the zooplankton), and Dr. G. W. Jeffers the vertical distribution of this food in the water. Dr. H. I. Battle investigated the capture and digestion of the food organisms by the herring under controlled laboratory conditions.

ACKNOWLEDGEMENTS

The authors are indebted to Mr. E. G. Rigby, Curator of the Atlantic Biological Station, for very considerable assistance in various ways during the course of the investigations. Fishery inspectors F. A. Batson and O. A. Rigby also rendered distinct service. The firm of Connors Bros. of Blacks Harbour made its laboratory available. The staff of that firm and also various weir operators in the district were most liberal in furnishing us with the necessary samples of herring as well as pertinent information.

FATNESS

Methods

The fatness of the herring may be variously defined and determined. For the present study a simple means of estimating it was used, and this consisted of measuring and weighing the fish. The degree of fatness was then determined by calculating the commonly used condition factor, which is $\frac{100 \times W}{L^3}$, where W = weight in grams, and L = total length of fish in centimetres. The measuring and weighing were performed while the fish were fresh in order to avoid the shrinkage which occurs on preservation. The amount of water on the surface of the fish could not be very perfectly controlled, which introduced an error. Also no attempt was made to remove or allow for the variable contents of the alimentary canal.

Samples of herring were obtained from the stationary herring traps or weirs which are operated in nearly all parts of the region. As the herring were not taken in the weirs regularly, and as the season was a poor one, it was rarely possible to secure samples at the time and place desired, so that it was necessary to utilize as best one could the material available.

Results

The condition factor was found to vary within rather wide limits. For example it ranged, in herring of 16 cm. total length, from 0.45 (held and fed in laboratory tank from July, 1933, and weighed Jan. 2, 1934) to 1.02 (Calder beach, Campobello, July 7, 1933, from weir in which the surface water felt gritty owing to the numbers of *Calanus*, the herring having their stomachs full of recently swallowed *Calanus*). The weights in these cases were 18.5 and 41.75 grams respectively. We did not succeed in getting any very lean fish during the summer, as the district where they were to be expected (Oak bay) reported the herring to be unusually fat. A 25 cm. fish taken at Calder beach, July 7, had a condition factor of 1.17, and doubtless even higher values could have been found. The fish became very thin in a few weeks when held in confined waters with a dearth of food, such as Kitty cove near St. Andrews (figure 1), and Dark harbour, Grand Manan. This has been frequently observed and being the usual procedure for Dark harbour gives that place the reputation of having the very poorest fish in the whole region. On the other hand where the food is abundant, the closer con-

finement of a weir does not prevent full feeding, and, when poor fish come to such a locality as Harbour de Loutre, they soon fatten up (Alex. Calder), this apparently being a matter of several weeks.

During July, August and September, 1933, seventeen samples in all were measured and weighed. Nine of these proved to be from localities and at times which made them more suitable for testing the reputed local differences in fatness, and these are first dealt with.

Three samples from localities at Campobello island (figure 1), where all agree that the herring are very fat, were as follows: Calder beach, July 7; Harbour de Loutre, August 31; Harbour de Loutre, September 18. Three, from Navy island, St. Andrews, whose herring were classed by three of the men referred to above as quite fat, and by one as medium, were as follows: "New Light" weir, July 14; "Atlantic" weir, August 22; "New Light" weir, September 13. Two, from the Perry shore, whose herring were classed by two of the men as medium compared with quite fat for Navy island (the others did not indicate a difference) were as follows: south of Loring cove, August 24; south of Gin cove, September 22. One was obtained from the "McCoubrey" weir, Oak bay, whose herring are classed as being poor, or by one of the men as very poor.

The values of the condition factor for each size group in each of the samples have been plotted in figure 3, those for each month separately.

None of the herring that have been considered had reached sexual maturity, mature fish being very rare in the region. As the largest of the immature herring, which are known locally as "stringers" and range in length from 24 to 30 cm., are rarely found inside the passages at the mouth of the bay, and, while present in all three of the Campobello samples, occurred in only one of the other samples and as a solitary specimen, attention has been confined to the still smaller sizes, namely "brit" (8 to 10 cm.), "snippers" (11 to 13 cm.), "oils" (14 to 18 cm.), and "mustards" (19 to 23 cm.). "Brit" and "snippers" are fish approximately a year old, which attain that size (and hence appear in the catches) from about the middle of the summer on. During the second summer the fish grow through the "oil" stage to that of the "mustard". The material, therefore, consisted mainly of fish of two different year classes, hatched in 1931 and 1932. The former were approximately from 13 to $20\frac{1}{2}$ cm. long in July, and from $15\frac{1}{2}$ to 23 cm. long in September.

The 1932 year class was unrepresented in the July samples, occurred as "brit" and "snippers" in one of the August samples, and was present in all three of the September samples, ranging from "brit" to "oils".

Since, with slackening in the rate of growth, there tends to be somewhat progressive increase in fatness from "brit" to "stringers", as is fairly well shown in figure 3, it has been thought necessary to keep the sizes separate in order to distinguish clearly any local differences in fatness. Also there are known to be seasonal differences in fatness, the herring being poorest in the spring before active feeding begins. Consequently it has been thought best to compare only those samples taken in the same month.

It will be seen in figure 3 that for the July samples the Campobello fish had a distinctly higher condition factor than those of the other two samples, and

would well be called very fat. Although they had been held in the weir for a week, a great abundance of food (chiefly *Calanus*) was provided them in the weir by the tidal currents as observed when the fish were obtained. The Navy island

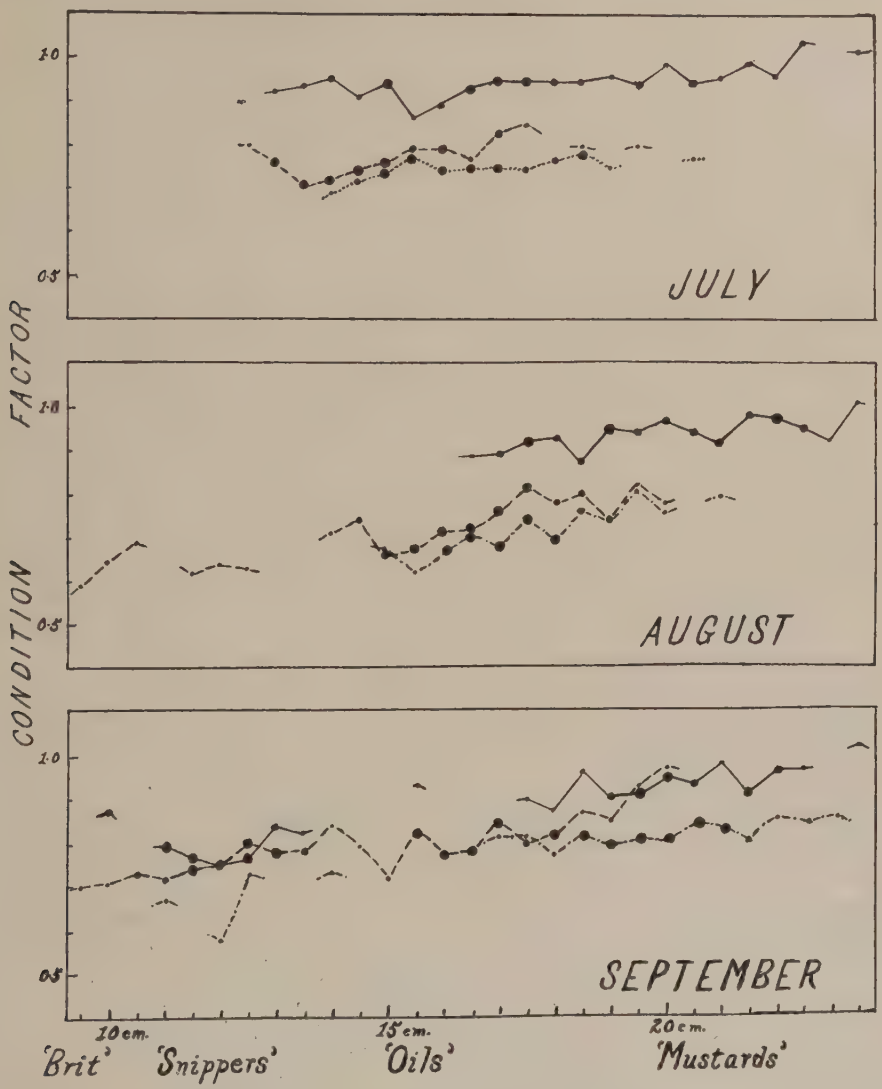

FIGURE 3. Condition factor for the various size groups in samples of herring from different localities. Large and small dots represent large and small numbers respectively examined for the various size-groups. Lines connecting points as follows: ———— Campobello island; – – – – Navy island; —·—·—·— Perry shore; . . . . . Oak bay.

fish had consistently a higher average value for each size group than those from Oak bay, but the differences are not as great as would be expected on the basis of the former being quite fat and the latter poor, as is reported to be usually the case. Mr. Fred McCoubrey has operated this particular weir in Oak bay for 19

years. In the previous 18 years he has known the herring to be "feedy" only in two different weeks, one in one year and the other in another. In the early summer of 1933 they were again "feedy", which is thus a most unusual condition in this bay, and undoubtedly responsible for the herring being, according to him, unusually fat for the locality.

The August samples (see figure 3) again showed the Campobello fish to be very fat in comparison with the others. While the Navy island and Perry shore fish were not uniformly different from each other, the former were on the whole definitely fatter. As the Perry shore is intermediate in location between Campobello and Navy island, this would not be expected, yet it agrees with the reported estimations of comparative fatness.

The September samples show a similar, but less definite, condition. The Campobello fish were on the whole not so fat as previously (a paucity of food had been evident for several weeks), and the Navy island and Perry shore fish were on the whole fatter than before. Nevertheless for the most part the Campobello fish were the fattest, and Perry shore fish the poorest, showing the reputed order.

The pertinent facts may be presented more simply in another way, although at the expense of details. Ignoring differences in fatness due to size, and taking the range from 15 to 20½ cm., which includes sizes that were most generally abundant, the fatness of the fish in a particular sample may be taken to be sufficiently well represented by the mean of the condition factor for all fish within the stated range. In table I are given the values of this mean for the samples already dealt with and for others that seem of significance, including some obtained in the early part of the summer of 1934.

It will be seen that, corresponding with report, the Campobello samples uniformly have the highest values. In June of 1934 the herring from Oak bay failed to be less fat than those from St. Andrews, the value being actually a little higher, though the difference cannot be considered significant.

The district of greatest abundance of herring and the district reputedly with the fattest herring are both at the mouth of the Inner or Passamaquoddy bay, but they are distinct. The former is to the northeast near Little Letite passage and goes by the name of "Channel" (figure 1), being a complex of islands and shallow, tortuous channels. The latter is to the southwest, being related to the deep, main Quoddy passage, and includes Harbour de Loutre, Friars bay, and Cobscook bay. The herring are not only more uniformly abundant in the "Channel" but they are decidedly more abundant there during the principal feeding and growing season in the early part of the summer than at Campobello. While the fishermen near the "Channel" state that the herring at Campobello are the fatter, only two of the four men who estimated relative fatness for us indicated such a difference. Does it exist? Mean values for the condition factor in samples taken in July, 1933, from three weirs ("Gleaner", "Syndicate" and "Fox Passage") located in the "Channel" district, are given in table I. They vary, but all are very considerably lower than the value for the Campobello sample, 0.75 to 0.83 as compared with 0.94. Similarly a sample taken on September 18 from Mowatt id., which is near the "Channel", but between the latter and Campobello, had a value of 0.82 as compared with 0.92 for a Campobello sample

taken on the same day. During the summer of 1933 the herring were more uniformly abundant in the "Channel" than at Campobello. The conclusion seems warranted that in this case, where the herring are most uniformly abundant, they are less fat than in an adjacent district.

TABLE I. Mean value of condition factor for herring from 15 to 20½ cm. in length

	July, 1933	August, 1933	September, 1933	June, 1934
Campobello	0.94	0.92	0.92	0.75
Deer island region				
Mowatt id.			0.82	
"Gleaner"	0.83			
"Syndicate"	0.75			
"Fox Passage"	0.78			
Perry shore		0.71	0.80	
St. Andrews	0.80	0.75	0.83	0.63
Oak bay	0.76			0.64

FEEDING

In order to provide a background of knowledge for an understanding of feeding in nature, which would presumably be the basis of local differences in fatness, the feeding of the herring was studied experimentally in the laboratory.

METHODS

When herring were being seined in a weir, some were permitted to pass into a galvanized iron tub as soon as the seine had been sufficiently pursed. When in the tub they were protected from direct sunlight; the water was frequently renewed and also kept cool with blocks of ice. In this way individuals from 9 to 20 cm. in length could be brought to the laboratory in excellent condition. As the technique improved the mortality fell from 33% to 6%, in the latter case for 200 fish on August 28. They all took food readily by the third or fourth day.

The tanks were entirely of concrete construction and situated on the floor of a windowless basement, provided only with artificial lighting and that from above. The tanks had each a capacity of 900 litres and the water, which was constantly renewed, ranged in temperature from 11.5 to 14.5°C.

RESULTS

Non-living food, consisting of clam (*Mya*), mussel (*Mytilus*), etc., when minced finely and dropped into the tank, was accepted readily, but only when rapidly moving. As it failed to remain suspended long, little of it was taken by the herring.

Mysis, *Gammarus*, and larvae of the lobster (*Homarus*) were captured by herring 15 cm. long, but had the habit of keeping to the sides or the bottom of the tank and were rarely observed by the fish.

Hyperia galba, obtained from specimens of *Aurelia*, floated near the surface, and twenty-seven of them were seized in five minutes in a tank containing forty fish, which corresponds with it and other Hyperiid amphipods being reported as

forming an important part of the food of the herring in European waters (Hardy 1924, p. 25).

Thirty specimens of the Euphausiid crustacean, *Meganyctiphanes*, were placed in a tank with the same number of herring, 14 to 15 cm. long. Only after thirty to thirty-five minutes did the fish seem to observe and commence attempts to capture them. In no case did they succeed the first time, nor was any fish seen to snap at the same shrimp twice consecutively. After an hour, by which time nine shrimp had been captured, the fish for the most part returned to the non-feeding parallel formation. The failure to feed upon *Meganyctiphanes* may have been due to size relations, since among herring from the weirs only the larger ones (around 20 cm. length) and sometimes only certain of these, were usually found to have eaten *Meganyctiphanes* which is an important food for still larger fish. Moreover, experiments in 1934 showed that the herring will take dead *Meganyctiphanes* only when chopped in pieces.

But when specimens of the copepod *Calanus* were added to the amount of an average of 8.3 individuals per litre, the fish in three to four minutes broke ranks, began independent rapid movements about the tank, occasionally breaking the surface. They concentrated where the *Calanus* were most abundant. A herring would, in capturing a *Calanus*, come up to it from beneath, and would alter its course to do so, turning somewhat on its side and partially opening its mouth. Probably the *Calanus* is noticed when coming between the eye of the fish and the principal source of light (in this case an electric bulb near the ceiling of the basement). The fish may make a second dash, if the first one proves a miss. Other copepods, viz., *Eurytemora*, *Pseudocalanus*, *Tortanus*, and *Acartia*, were all taken similarly by a definite act of capture.

The herring were tested as to their ability to feed under various intensities of lighting. In tables II and III are given the results of two typical experiments. It is probable that the two and four copepods found in herring after being in the darkness for 2 hours and 5 minutes, as shown in table II, were taken before the ceiling light was turned off when the experiment was started. The two herring marked "(dis)" were found to be in a diseased condition and should be disregarded.

It is very evident that the herring are unable to feed in the dark. While able to feed slowly in the dim light of two 15-watt bulbs placed $7\frac{1}{2}$ metres above the water surface, when the light was increased to twenty-eight times the intensity (one 15-watt bulb, 1 metre above the surface) feeding was increased, with *Calanus* as the food, to somewhat more than five times the previous rate, and, with the smaller copepods as the food, to slightly over four times the previous rate. In this, no allowance is made for slowing in the rate of feeding as the result of repletion. The facts warrant the assumption that there was no significant alteration in the concentration of the copepods during the experiment.

Discussion

Moore (1898, p. 402) has stated that the herring chases and seizes Euphausiids individually, but, when eating copepods, "it appears to pay no attention to indi-

viduals but merely to swim open-mouthed and takes its food en masse." The view that this latter method is used has had considerable vogue, but our observations in nature and in the laboratory have failed to reveal any basis for it. Bigelow, on the basis of observations made on herring kept in a tank with menhaden, states (1926, p. 101) that "they select (the organisms) individually and not by swimming open-mouthed as the menhaden does". It seems clear, therefore, that the herring must depend upon seizing individual organisms or food particles. Hardy (1924, pp 27 and 28) has summarized the European data with the same conclusion.

TABLE II. Capture of *Calanus* by herring (50 in 900 litres) with variable illumination, initial concentration of *Calanus* being 13.3 per litre

After 2 hrs. 5 min. of darkness		After additional 1 hr. 5 min. with two 15-watt bulbs, 7½ m. above		After additional hour with one 15-watt bulb 1 m. above	
Fish length in cm.	Copepods in caecum	Fish length in cm.	Copepods in caecum	Fish length in cm.	Copepods in caecum
10	0	9	17	9	48
14	0	12	5	14.5	62
15.5	2	15	3	15	89
16	0	17	18	16	53
18	4	18	12	19(dis)	0

TABLE III. Capture of *Eurytemora*, *Tortanus*, and *Acartia* by herring (45 in 900 litres) with variable illumination, initial concentration of copepods being 73.3 per litre

After 1 hr. 10 min. of darkness		After additional hour with two 15-watt bulbs, 7½ m. above		After additional hour with one 15-watt bulb 1 m. above	
Fish length in cm.	Copepods in caecum	Fish length in cm.	Copepods in caecum	Fish length in cm.	Copepods in caecum
15	0	15	28	15	431
15	0	15	68	15	265
15	0	15	7	15(dis)	10
15	0	15.5	116	15.5	342
15.5	0	15.5	93	16.0	210

The demonstration that herring fail to feed in darkness agrees with the experience of the Passamaquoddy fishermen that the herring contain more food after moonlight nights. Mužinić (1932) found that, roughly, feeding stopped between 9 p.m. and 4 a.m., so that very little food was found in the stomachs at midnight. Moore (1898, p. 402) states that "when feeding at the surface whether upon shrimp or copepods they are said to be 'schooling', a phenomenon more common at night than during the day and according to fishermen more prevalent upon moonlight nights than during dark and cloudy ones." This surface feeding is readily recognized at night by the noise made when the fish break the surface in seizing their food, which we can affirm from personal experience.

It would seem that when the fish are at the surface the difference between moonlight and starlight is significant in stopping or at least slowing down the feeding process. The two illuminations used in our experiments were of an intensity somewhat near that of moonlight, and, therefore, our results may be considered to have given experimental proof of conclusions based upon observations in nature.

Some of the fish were kept throughout the autumn and winter, being fed quite regularly by Mr. E. G. Rigby, who observed their behaviour. On February 1, 1934, with the temperature of the water at 0.75°C., they seemed sluggish and inclined to stay at the bottom of the tank, but took the copepods (chiefly *Calanus*) that were introduced, and fed steadily. Overnight, with the light kept on, the copepods all disappeared, but there was no indication that the fish had taken any of the Euphausiids introduced, which they cannot capture so readily.

DIGESTION

For a better understanding of the process of conversion of food into fat, it seemed desirable to obtain information as to the time involved in digestion. There was also the question as to how long it would take herring to become clear of food material when confined, if no food should be available, since herring full of food are considered undesirable for canning owing to the action of the digestive juices on the tissues of the fish. Also interpretation of data on the food occurring in herring captured and held in weirs for a variable length of time should be based upon knowledge of the rate of digestion.

Methods

Samples of herring were obtained from representative weirs for which the approximate time in the weir was considered to be known. The alimentary canal of each fish was examined in order to ascertain how far digestion had progressed toward complete clearing.

Accurate data were obtained under experimental conditions by starving herring in tanks for two to three days and then feeding them in dim light with freshly captured copepods (*Calanus*, *Eurytemora*, *Tortanus*, *Acartia*, etc.) until they returned to the non-feeding, close, parallel formation, which occurred in approximately two hours' time. A sample consisting of three or more fish was removed to determine the quantity of food eaten, the caecum of the stomach usually being well distended, and giving a range from 15 to 21 for the ratio of one thousand times the weight of the food divided by the weight of the body. The fish were then kept in the same tank if the temperature was suitable, or transferred to another tank, the water of which could be kept by cooling or warming devices at some desired low or high temperature. At definite intervals samples consisting of two fish each were removed for examination of the digestive tract. Any food present in the stomach was weighed and the pH of the contents of each of the various parts of the digestive tract was determined by the B.D.H. capillator method. If no contents could be removed by a pipette from the lumen of the tract in any region, it was customary to wash it out with 2 or 3 drops of dis-

tilled water and to determine the pH of the rinsing. The pH determinations made possible a more exact determination of the time at which food passed from the tract and the secretion of digestive juices had ceased. Clearance of the intestine was difficult to ascertain with accuracy. An arbitrary standard was chosen as the time at which microscopic examination of the contents revealed the presence of no chitinous debris and the chyme had definitely changed from a semi-viscid orange mass coloured by crustacean oils to a greenish-yellow watery fluid consisting largely of bile.

Results

Fourteen samples from eleven weirs in the region were examined as to the percentages in each sample of four stages of digestion, (1) caecum with food, (2) food in pylorus, but not in caecum, (3) food in intestine only, and (4) empty. An example will show how the results varied. Table IV gives the data for the "Gleaner" weir, at Parker island in the "Channel" district (figure 1). Samples taken presumably of the same lot of fish on two successive days show very little difference in the food conditions, in spite of the fact that those of the second day, having been held 24 hours longer, should have been well cleared. Also a second sample obtained, not from the pound but from the main part of the weir, on the second day, though presumed to have been as long in the weir as the sample on the first day, showed very much more recent feeding. Evidently there are unknown variables that prevent proper interpretation of the results.

Table IV. Food conditions in samples of herring from *Gleaner* weir, shown as percentages

Date	Time in weir (hours)	Number examined	Lengths (cm.)	Percentages with food in			% with no food
				Caecum	Pylorus	Intestine	
July 28..	12	366	14–25	4.3	30.1	36.1	29.5
July 29..	36	223	13–22	0	26.0	52.9	21.1
July 29..	12	172	14–20	59.9	31.9	8.2	0

The laboratory experiments, in which there was control of both temperature and feeding, yielded very uniform results. Temperatures as low as 6° and as high as 20°C. were employed. With the latter, the first three attempts were unsuccessful, as the fish rapidly regurgitated their stomach contents at this temperature, but the fourth attempt succeeded. In table V are given the data for an experiment at 13.0°C., which may be taken as typical of the series. It lasted ten days in all.

The results given in table V have been in part represented graphically in figure 4 and indicate the more acidic nature of the stomach contents while food is in the process of digestion, as well as the increase in acidity of the intestinal contents consequent upon the passage of food and large quantities of bile (pH 5.8) into the latter organ.

TABLE V. Conditions as to hydrogen-ion concentration (pH) in various parts of the digestive tract of herring kept at 13°C. during course of an experiment in which *Eurytemora*, *Temora*, *Tortanus* and *Acartia* were fed. The time was when feeding (lasting two hours) began, the fish having been without food for two days

Time (hrs.)	Lengths (cm.)	Cardiac stomach	Caecal stomach	Pyloric stomach	Pyloric caeca	Ant. intestine	Mid-intestine	Post intestine	Bile	Observations	Food wt. / Body wt. x 10^3
0 Starved.....	15.0	6.9	6.9	7.0	7.2	7.5	7.7	7.8	5.8	Bile emerald	0
	15.5	6.8	6.6	6.6	7.3	7.6	7.7	7.8	5.8	green	0
1 Half fed.....	15.5	4.6	4.5	4.6	6.7	6.9	6.7	6.8	6.0	Bile	10
(1 hr.).....	15.5	4.4	4.0	4.4	6.5	6.6	6.5	6.7	5.9	greenish yellow	7
3 After feeding	15.5	4.3	4.2	4.7	6.3	6.4	6.4	6.4	6.1	Bile yellowish brown.	18
	15.5	4.2	3.9	4.4	6.2	6.4	6.5	6.5	6.0	Food pink	15
4½ " "	16.0	4.4	4.3	4.7	6.3	6.5	6.4	6.4	6.2	Bile brownish	18
	15.0	4.6	4.5	4.6	6.3	6.4	6.4	6.4	6.1	yellow	14
6 " "	15.0	4.3	4.4	4.5	6.1	6.4	6.5	6.4	6.0	Bile yellowish	16
	15.3	4.6	4.9	4.7	6.4	6.6	6.6	6.7	6.1	green	8
8 " "	15.4	5.3	5.2	4.6	6.2	6.4	6.5	6.5	6.0	Bile darker green,	12
	15.5	5.5	5.3	4.8	6.4	6.4	6.6	6.7	5.9	Food in pylorus, little in caecum	9
10 " "	15.0	5.4	5.3	5.1	6.4	6.6	6.6	6.6	5.9	Bile emerald green	5
	15.2	5.7	5.5	4.8	6.5	6.5	6.7	6.7	5.8	Food mainly in pylorus.	5
14 " "	15.6	5.9	5.7	5.2	6.5	6.7	6.7	6.8	5.9	3 copepods in stomach	5
	15.2	6.0	5.9	5.6	6.7	6.8	6.7	6.7	6.0	Only chyme in stomach	0
15 " "	14.7	6.2	6.2	5.9	6.6	6.7	6.8	6.9	5.9	Bile emerald green	0
	14.9	6.0	6.4	6.3	6.8	6.8	6.8	6.9	5.8	Food all in intestine	0
18 " "	15.0	6.5	6.5	6.6	6.7	6.7	6.9	7.0	5.8		0
	15.3	6.4	6.4	6.5	6.9	6.6	7.2	7.3	5.9	Food all gone—even chitin	0
22 " "	14.8	6.5	6.6	6.6	6.9	6.9	7.3	7.3	5.8		0
	14.6	6.7	6.8	6.7	7.0	7.0	7.4	7.4	5.8	Empty. Bile emerald	0
26 " "	15.0	6.7	6.8	6.7	7.2	7.2	7.5	7.6	5.8		0
	15.2	6.7	6.8	6.7	7.2	7.6	7.8	7.9	5.8	" " "	0
50 " "	15.0	6.8	6.9	6.9	7.4	7.6	7.9	8.0	5.9		0
	15.6	6.6	6.7	7.1	7.3	7.4	7.8	7.8	5.8	" " "	0
74 " "	14.8	6.6	6.9	7.0	7.3	7.2	7.6	7.7	5.8		0
	16.0	6.7	6.9	6.7	7.3	7.4	7.8	7.7	6.0	" " "	0
98 " "	15.2	6.7	7.0	7.1	7.4	7.4	7.9	7.6	5.8		0
	15.0	6.7	6.8	6.7	7.3	7.6	7.5	7.8	5.8	" " "	0
170 " "	14.6	6.7	6.8	6.7	7.3	7.5	7.6	7.2	5.8		0
	15.0	6.8	6.7	6.7	7.3	7.6	7.6	7.8	5.8	" " "	0
194 " "	15.0	6.7	6.9	6.7	7.2	7.7	7.9	8.0	5.8		0
	15.5	6.7	6.9	6.5	7.5	7.9	8.2	8.0	5.8	" " "	0

Using the same procedure, determinations were made of the rate of clearing of (*a*) stomach, (*b*) whole digestive tract, and the results are given in table VI. The rate of clearing of the stomach is a very gradual process with food remaining for a long period in the pylorus, hence we find that the whole digestive tract is cleared in a relatively short time after the last food has passed through the stom-

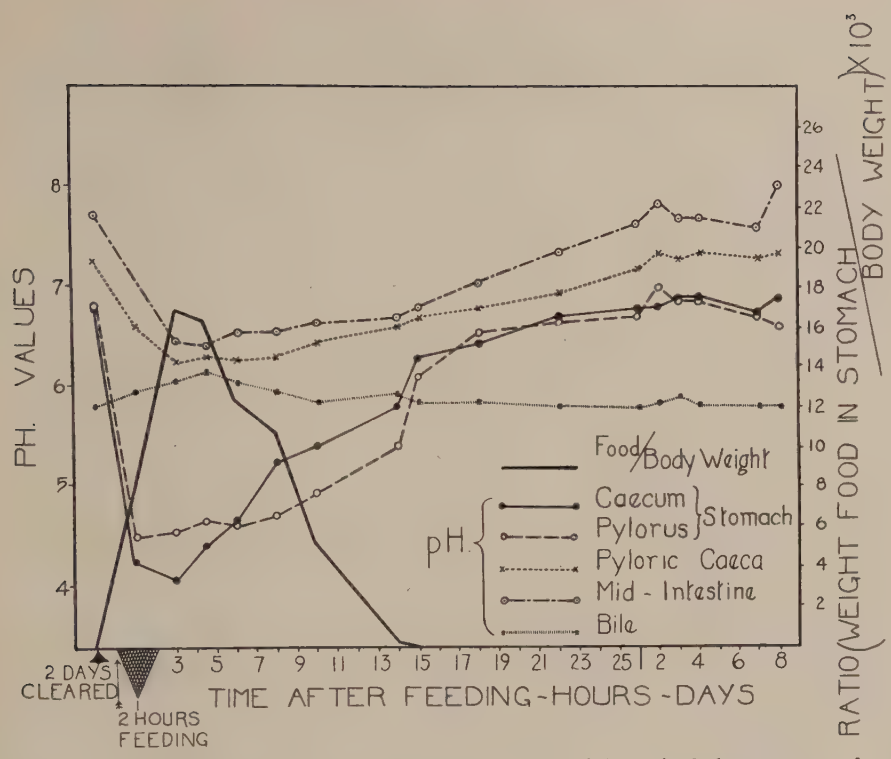

FIGURE 4. Changes in hydrogen-ion concentration of the bile and of the contents of various portions of stomach and the intestine in herring 14 to 16 cm. long, during digestion.

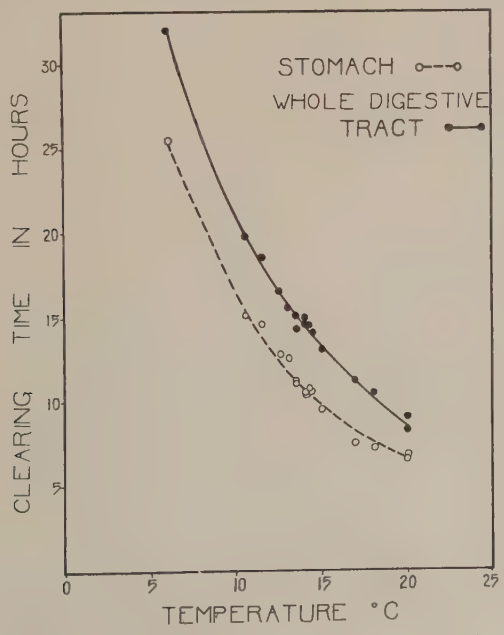

FIGURE 5. Effect of temperature on the time required for the stomach and for the whole digestive tract of the herring to clear, after feeding.

ach. The results given in table VI have been plotted in figure 5. The temperatures (°C.) appear as abscissae and the time in hours required for the passage of food through the digestive tract as ordinates. The curves are what might be expected for reaction curves, the time for digestion decreasing as the temperature increases. Using the data obtained experimentally we find according to van't Hoff or the R.G.T. rule that Q_{10}, the temperature coefficient for given temperature intervals, is within the physiological limits of 2 to 3.

TABLE VI. Rate of clearing (as shown by the time in hours) of stomach and whole digestive tract from food at different temperatures. *Eurytemora*, *Temora* (?), *Tortanus* and *Acartia* used as food, except where starred*, in which two cases *Calanus* and *Pseudocalanus* were used.

Temp. °C.	Stomach	Whole tract
6.0	25½	32
10.5	15	19¾
11.5	14½	18½
12.5	12¾	16½
13.0	12½	15½
13.5	11	15+
13.5	11+	14¼+
14.0*	10½	14½
14.0	10½	14¾
14.2	10¾	14½
14.5	10½	14
15.0	9½	13
17.0	7½	11¼
18.0*	7¼	10½
20.0	6½	9
20.0	6¾	8¼+

In figure 6 the log of the rate of clearing has been plotted as an ordinate and the reciprocal of the absolute temperature as abscissa. This gives for both stomach clearing and clearing of the whole digestive tract a straight line relationship. The value of μ or the critical thermal increment has been calculated and found to be (over the range from 6° to 20°C.) 16,600 for the clearing of the stomach and 16,100 for the corresponding process in the whole digestive tract. These closely approximate the values given by Crozier (1924) for biological oxidations at ordinary temperatures.

In one instance a number of 9 to 12 cm. fish were fed along with 15 cm. specimens at 14°C. On examining a number of these fish later it was found that the clearing process required somewhat over three hours longer than for the larger fish. Further experimental work along this line was impossible owing to the inadequacy of time and material. That small fish do clear less rapidly than large may, however, be a fact as is shown by comparing the quantities of food in the stomachs of fish of various sizes removed from weirs together. An examination of table VII shows that, although fish in any one lot have been in a weir the same length of time, all smaller fish contain consistently more food per body weight than larger ones with the possible exception of those taken at "Fox Passage" weir on July 27, 1933. It is probable, however, that the food organisms available in or near the weir are small and, therefore, more suitable for the smaller fish.

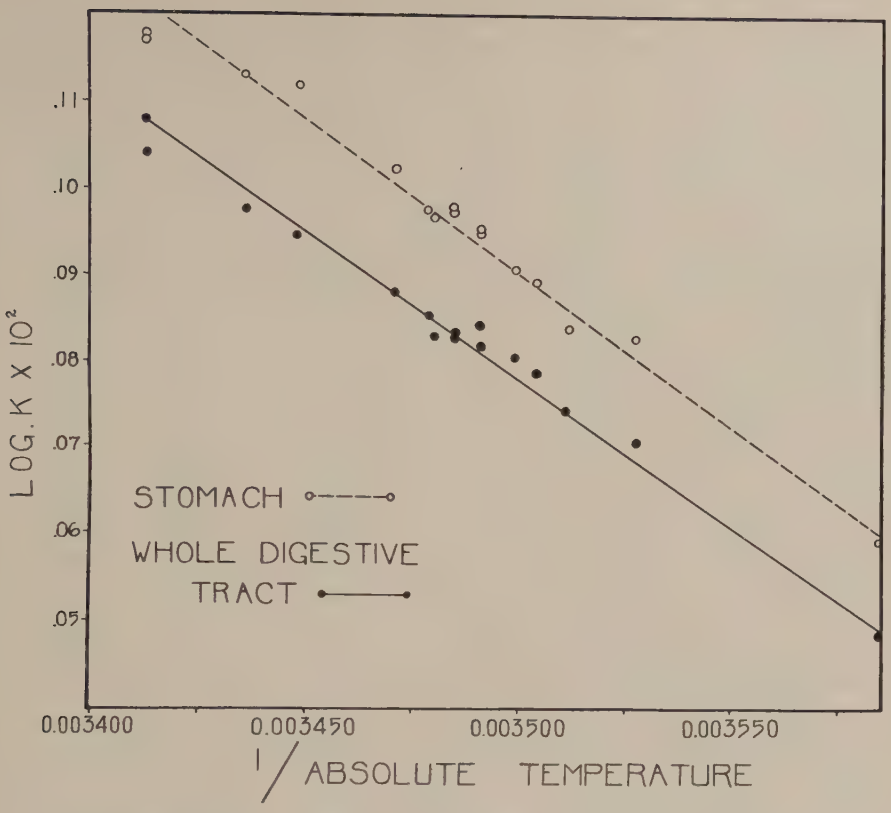

FIGURE 6. Relation of rate of clearing of the digestive tract of the herring from food to the absolute temperature.

THE FOOD IN THE HERRING

METHODS

The herring in the various samples were measured to the nearest centimetre and placed in length groups, each with a range of three centimetres, e.g., 15 to 17 cm., 18 to 20 cm., etc. The stomachs of approximately fifty herring were taken from each sample and preserved in 4% solution of formaldehyde, those of each length group being kept separately. The contents of the stomachs were subsequently examined microscopically to determine the nature of the food organisms and their relative numbers.

RESULTS

In all, thirty-two samples were examined, as will be seen in detail in table VIII. Four samples from Campobello showed food present in 67%. The Euphausiid shrimp, *Meganyctiphanes norvegica*, and the copepods, *Calanus finmarchicus*, *Pseudocalanus elongatus* and *Acartia clausi*, formed practically the

TABLE VII. Weight of food in stomach of herring after preservation in 5% formaldehyde

Weir	Date	Length (cm.)	No.	Weight fish (gm.)	Weight food (mgm.)	$\frac{\text{Food (gm.)}}{\text{Body (gm.)}} \times 10^3$
Fox Passage....	July 27	12–13	15	319	4,162	12.1
		14–15	27	655	6,322	9.6
		16–17	19	635	6,810	10.7
		18–20	14	669	830	1.2
Fox Passage....	July 28	13–15	21	498	364	0.73
		16–17	20	647	184	0.27
		18–19	13	560	53	0.09
		20–21	2	148	10	0.07
Gleaner.....	July 28	14–15	29	938	532	0.56
		16–17	22	958	120	0.12
		18–20	15	832	23	0.03
Gleaner (Lot A). (pound)	July 29	11–13	15	381	502	1.3
		14–17	49	1,559	1,149	0.73
		18–22	10	817	38	0.05
Gleaner (Lot B). (main weir)	July 29	14–15	23	680	11,762	17.3
		16–17	11	472	4,947	10.5
Syndicate.....	July 28	14–15	17	421	163	0.38
		16–17	25	859	75	0.09
		18–20	9	427	25	0.06
Porr's Pt.....	July 28	14–15	17	455	756	1.7
		16–17	17	633	240	0.37
		18–19	12	623	142	0.22
		20–22	8	653	50	0.07
Sand Reef.....	July 29	14–15	13	265	1,172	4.4
		16–17	20	603	2,041	3.3
		18–19	8	327	320	0.98
		20–21	7	352	200	0.56
Boyd's (L'Etang)	July 29	14–15	33	815	5,230	6.4
		16–17	15	533	1,335	2.5
		18–20	3	171	432	2.5
Hooper.....	July 29	14–15	9	169	215	1.3
		16–17	14	409	392	0.96
		18–19	20	830	730	0.88
		20–22	2	416	163	0.49
Biol. Station....	Aug. 8	14–15	19	422	2,124	5.0
		16–17	16	505	270	0.53
McCoubrey.....	July 17	14–15	6	145	30	0.21
		16–18	10	384	20	0.05

entire food, the first ones tending to be in the larger fish and the last ones in the smaller. The first two forms occurred more regularly than the last two.

In seven samples from the "Channel", food was present in 69%, showing a similar condition to that at Campobello. Unlike the latter locality, however, *Eurytemora* was an important food item in three of the samples, and *Acartia* did not appear.

Only one sample was obtained from the Perry shore. Only 11% and these the smallest (9 to 11 cm. long) contained food, which consisted of *Temora*, *Calanus*

and *Acartia*, in that order of abundance. There were occasional mackerel present that might have prevented feeding. However, on the same date herring at St. Andrews point ("Protection" weir) had many mackerel and 40% of the herring, including all sizes, had food.

In eight samples from Navy island (table VIII) 53% of the herring contained food. *Temora longicornis*, *Eurytemora herdmani*, and *Tortanus discaudatus* were the principal forms in the food. *Acartia clausi* was not infrequent. *Pseudocalanus elongatus*, *Calanus finmarchicus*, and *Meganyctiphanes norvegica* occurred less often and only on the west side of the island ("Atlantic" and "Grimmer" weirs). The striking feature is the almost complete replacement of the large *Meganyctiphanes* and *Calanus*, which with the small *Pseudocalanus* and *Acartia* formed the entire food at Campobello, by three relatively small copepods, *Temora*, *Eurytemora*, and *Tortanus*. Corresponding with this the herring had less and less food going from the smaller ones to the larger.

TABLE VIII. Food in samples of herring from Campobello island to Oak bay, season of 1933

Locality	Weir	Date	Percentage	Nature of food
"Channel"	Gleaner	July 28	40	*Eurytemora*
"	"	July 29	100	*Eurytemora, Calanus Meganyctiphanes Pseudocalanus*
"	Syndicate	July 28	82	*Pseudocalanus*
"	Otter	July 29	60	*Calanus, Pseudocalanus*
"	"	Aug. 22	66	" "
"	Fox Passage	July 27	58	*Calanus, Eurytemora, Meganyctiphanes*
"	" "	July 28	74	*Pseudocalanus, Meganyctiphanes*
Campobello	Calder Beach	July 7	88	*Calanus, Pseudocalanus*
"	Porr's Point	July 28	78	*Acartia, Meganyctiphanes*
"	Porr's Point	August 10	84	*Calanus Meganyctiphanes,*
"	Biddy Brook	August 31	40	*Meganyctiphanes, Calanus*
Perry shore	?	August 24	11	*Temora, Acartia, Calanus*
Navy island	New Light	July 14	100	*Eurytemora, Temora*
"	Atlantic	August 22	7	*Calanus, Pseudocalanus*
"	New Light	August 28	73	*Temora, Tortanus*
"	" "	August 30	96	*Temora, Eurytemora*
"	" "	September 8	15	*Temora, Eurytemora, Acartia, Tortanus*
"	Graball	September 8	78	*Temora, Eurytemora, Acartia*
"	Atlantic	September 8	32	*Temora, Eurytemora Meganyctiphanes Acartia, Pseudocalanus,*
"	Grimmer's	September 8	31	*Temora, Eurytemora Calanus, Pseudocalanus*
Oak bay	McCoubrey	July 17	0	

The single sample of herring from Oak bay obtained on July 17 showed no food whatever.

Discussion

It is quite evident that too many factors are involved to permit our reaching any finality as to local differences in the amount of food taken by the herring, as indicated by such limited samples of herring taken from weirs in which they had been confined for unknown numbers of hours. Local reports are, however, of distinct value.

The absence of food in the single sample of herring from Oak bay agrees with the experience of Mr. F. McCoubrey, the operator of the weir, that only very exceptionally during his nineteen years' experience has he found the fish to be "feedy". This condition will explain the reputation of the fish of this locality as being the poorest in the region with the exception of those shut up in Dark harbour, Grand Manan.

For Navy island, Mr. Wellington Carson, who operates the "Atlantic" weir, states that the fish taken in it are not very often "feedy" enough to interfere with their sale. If "feedy", they clear in 24 hours' time. They contain "red feed", that is copepods, and rarely "shrimp", that is Euphausiids (*Meganyctiphanes*). The "shrimp" are never observed in the water. Usually the fish have the most food after a moonlight night. In correspondence with this the herring taken in the "New Light" weir on August 30 after a moonlight night had considerably more food (table VIII) than those taken in the same weir two days previously after a moonless night (heavily overcast). Also the food consisted of *Temora* and *Eurytemora* in place of *Temora* and *Tortanus*. The facts, therefore, show that in this locality food, while rather steadily available, is somewhat restricted in amount, is not in evidence at the surface, and consists principally of the smaller species of copepods, which are not so readily taken by the larger fish. Also the herring in this locality tend to feed chiefly on moonlight nights. This corresponds with the herring taken locally having the reputation of being either fat or only medium.

The limited amount of information available for the Perry shore indicates poorer feeding conditions than at Navy Island, which agrees with the reputation of the local fish as being somewhat less fat.

Somewhat sharply contrasted with the conditions just described is that in the main passages at the mouth of the bay. This contrast is recognized for places as close together as Northern harbour on the Inner bay side of Clam cove head (figure 1) and Fairhaven on the Quoddy river or passage side of the same head. Mr. Frank Wentworth states that there is a definite difference; "feedy" fish in Northern harbour clear in 24 hours when in the weir, but do not do so at Fairhaven because they feed in the weirs. At this place as well as at Campobello, that is at both ends of the passage, Euphausiids ("shrimp") are sometimes seen cast up on the beach in windrows. Mr. Oliver Allingham of Welchpool, Campobello, states that about twenty years ago the shrimp (Euphausiids) were in such masses on the beach of Friars bay that three or four cartloads were hauled up for

manuring the land. In 1933 fair quantities were reported as cast upon the beach. The whole passage is considered to have very 'feedy" fish, and the general experience seems to be that expressed by Mr. Arthur Haney, who operates a weir ("Black Prince") beside Doctor cove, which is not far from the mid-point along the passage. He states that he has a lot of trouble with feed in the herring, and that if there is any feed going, the herring have it. There may be so much feed being carried by the tides through some weirs in or near the passage, that the herring are not clear of it and saleable even after being kept a week or more. The feed, principally "shrimp" (Euphausiids), being large enough to be readily observed, is seen in the weirs at the surface and the herring are observed feeding. While some say that the herring are "feedier" after moonlight nights, others, e.g. Mr. Herbert Kelly, state that they have failed to notice any difference and Mr. W. H. Lord even states that herring entering a weir at night are "feedier" than those entering in the morning, which would be expected with food available to them near the surface during the day. All the evidence indicates that in this locality the fish can feed every day and do so in the daytime, the food being at the surface, that there is an abundance of both small and large forms of food suitable for all sizes of herring, and that consequently the fish are exceptionally fat.

THE HERRING IN THE WATER

The herring can feed only when they are where the food is to be found. There is evidence that they move about more at high temperatures than at low, and more before and after than during the principal growing (and feeding?) season from June to August; also that they are carried about in movements of the water (Huntsman 1934). They may or may not reach places where food is abundant.

It is not only important that the herring should be in localities where food is to be found but also that they should be at approximately the same depth in the water as the food. It has not been feasible to obtain precise data concerning the depth at which the herring swim.

However, in the Quoddy passages they may be seen or heard breaking the surface in feeding at practically any hour of the day or night when conditions are suitable, and their behaviour can be readily observed when they are in the weirs, which at high water may have a depth of as much as nine fathoms (about sixteen metres). All the evidence points to their keeping in the more superficial part of the water mass, at least during the summer season. Using a torch for the capture of the herring on a dark night was formerly not an uncommon practice in the region. An important element in their capture in the weirs is the attraction of moonlight or of the light from the sun when just below the horizon; and to some extent repulsion by the light from the sun when it is above the horizon causes the herring to enter or leave the weirs. Such reactions would tend to keep the herring during the day at some, but no great, distance below the surface, and observation tends to confirm this. The fact that they feed near or at the surface in the Quoddy passages during the day is not owing to there being more food near the surface, for the reverse is the fact. It may be due, however, to their method of feeding bringing them into stronger light than would otherwise be the case.

Nevertheless the non-feeding fish in close formation are visible, though at a greater depth.

THE FOOD IN THE WATER

Methods

To obtain the larger organisms in the water such as serve the herring for food, a net of cotton marquisette with approximately 225 meshes to the square centimetre corresponding to No. 0 bolting cloth, was towed through the water. The mouth, 30 in. (75 cm.) in diameter, was unobstructed in towing, a rope being attached on each side and a heavy lead weight suspended from the lower edge to keep the frame vertical.

The one motor boat, the "Sagitta", was used for all the collections, and its speed was kept uniform at approximately 1.05 miles per hr. (1.7 km. per hr.) by (1) fastening a board in a vertical position in the water below the stern, and (2) throttling the engine until the fly wheel had a rate of approximately 300 r.p.m. The *standard tow* was of 10 min. duration, when taken at a particular depth. *Comprehensive tows* covering equally all parts of a range in depth, for example from the surface to the bottom, so as to determine the quantity of food available in the water at any given place, were made as follows: with the boat in motion at the standard rate of speed, the net while being towed was lowered steadily at the rate of ten metres per minute from the upper to the lower limit of the desired range in depth. On reaching the lower level the process was reversed, the net being raised at the rate of ten metres per minute. Thus a range of fifty metres in depth (oblique) took ten minutes and corresponded to the standard tow. It was thus possible to obtain collections of the macroplankton, from which the comparative concentration of the food organisms could be determined for different depths or for different bodies of water.

The concentration of plankton at a particular place is arbitrarily taken to be the amount in a 10-minute standard tow covering the full range in depth. Owing to the danger to the net, a layer of variable thickness next the bottom has to be disregarded. The collections were received in fruit jars with a capacity of one pint (500 cc.), fastened in the small end of the net.

The quantity of the plankton was determined by putting the sample in a cylinder graduate, letting it settle until visible settling ceased, and then reading the volume of the settled portion. The samples were examined with both binocular and ordinary compound microscopes, but, as time did not permit an accurate enumeration of all the various species, only the larger forms such as *Sagitta elegans* Verrill, *Meganyctiphanes norvegica*, and *Clione limacina* Phipps were counted in each sample, while the copepods were merely divided into large and small. The large consisted almost wholly of *Calanus finmarchicus*, while the small included principally *Acartia clausi*, *Pseudocalanus elongatus*, *Tortanus discaudatus*, *Eurytemora herdmani*, and *Temora longicornis*. The total numbers of large and small copepods in a sample were calculated from the number counted in a definite portion, e.g. one-fiftieth.

Results

On July 21 comprehensive tows, going nearly to the bottom, were taken at

a series of nine stations from the mouth of Oak bay down the St. Croix estuary, across the mouth of the Inner bay and well out through the main passage beside Campobello island during the period from 10.30 a.m. to 4.00 p.m., the sky being clear or somewhat hazy. The positions of these stations are shown in figure 1 (nos. 18, 19, 20, 21, 13, 14, 5, 17 and 16,) and the data for the plankton taken are presented in table IX.

In this series the first four stations, which are in the St. Croix estuary from its mouth to the mouth of Oak bay, do not differ appreciably in the concentration (quantity in standard tow) of plankton from the last four stations, which are in the main Quoddy passage. The St. Croix stations, however, have (1) over twice as great a concentration (number of individuals per standard tow) of small copepods, (2) half as great a concentration of *Sagitta*, and (3) not much more than a hundredth the concentration of *Calanus*, as have the passage stations. The intermediate station (13) at the mouth of the Inner bay and off the Perry shore has much the poorest plankton.

TABLE IX. Plankton taken in comprehensive tows on July 21, 1933

Sta. no.	Locality	Depth (m.)	Quantity (cc.)	Large copepods (no.)	Small copepods (no.)	Sagitta (no.)	Concentration (cc. per 10 min. tow)
18	Mouth of Oak bay	0–25	13	0	27,000	2	26
19	St. Croix river....	0–28	24	40	47,600	2	43
20	" "	0–30	17	37	38,400	1	28
21	" "	0–30	14	2	48,100	1	24
13	Inner bay.....	0–60	13	154	10,900	2	11
14	Quoddy passage..	0–75	62	10,300	57,900	7	41
5	" "	0–50	15	1,300	16,200	2	15
17	" "	0–50	27	5,600	23,600	6	27
16	" "	0–50	40	11,100	27,100	11	40

These results fail to show differences in either local quantities or local concentrations of plankton to agree with the local differences in fatness and in abundance of food in the herring that have been described, except that the Perry shore station (13) has less plankton than either the Campobello station (17) or the Navy island station (21) although it is intermediate in position. That this is probably the usual condition is shown by other hauls. On July 5, 1933, a comprehensive tow, 0-50 metres, at station 13 gave only 7 cc. compared with 20 and 15 cc. respectively for 0-35 metre tows at stations 12 and 1 in the Inner bay and not far from Navy island, while on July 10 a 0-50 metre tow at station 17 gave 83 cc. Similarly, on September 26 the following quantities were obtained as indicated,—sta. 21, 0-30 m., 10 cc.; sta. 13, 0-50 m., 2 cc.; and sta. 35 (near Campobello), 0-50 m., 14 cc. It may be considered, therefore, as fairly well established that in the Inner bay, near its mouth and off the Perry shore there is ordinarily a comparative dearth of plankton for some reason or other.

If Campobello and Navy island do not differ significantly in respect to the quantity and concentration of the food animals in the plankton, it will be neces-

sary to find some other explanation of the greater fatness of herring at Campobello. A pronounced difference between the two places is known to exist as to the occurrence of the herring food near the surface. Many observations, both by visual inspection of the water and by taking superficial plankton hauls, have shown that *Meganyctiphanes*, *Sagitta* and *Calanus* are quite regularly at the surface near Campobello, but are not seen near Navy island. Since herring seem to keep near the surface and require light to capture their food, availability of the food organisms near the surface is of very great importance. Plankton tows were taken to determine this availability in some detail.

On July 27, tows at the surface and at 10 metres depth as well as comprehensive tows were taken to show on the one hand the gradation from Little Letite passage ("Channel") into the Inner bay (stations 27 to 29, figure 1), and on the other hand the condition in the main passage (station 17) and on the adjacent Campobello shore at Calder beach. The plankton data are given in table X.

TABLE X. Plankton taken from Little Letite into Inner bay and from the main Quoddy passage to the Campobello shore, July 27, 1933

Sta. no.	Depth (m.)	Quantity (cc.)	Large copepods	Small copepods	Sagitta	Euphausiids
27	0	11	96	16,500	0	0
	0–10	5	30	7,300	0	0
28	0	10	45	1,900	0	7
	10	14	22	37,800	0	0
	0–40	12	134	17,500	0	0
29	0	4	6	1,900	0	0
	10	19	9	5,300	0	0
	0–40	10	6	6,700	0	1
17	0	43	5,700	84,800	18	7
	0–50	45	12,200	58,200	10	0
Calder beach	0	152	44,300	192,400	103	3
	5	82	15,800	34,500	38	1

It will be seen that going from station 27 in the "Channel" to station 29 in the Inner bay there is a marked drop in the abundance of the food organisms, particularly at the surface, the principal forms decreasing 80 or 90%. As the tows were taken along the course of the flooding tide, there was the expectation that it would be much the same water in each case, nevertheless the usual difference (as seen on inspection from the boat) between passage and bay prevailed. At station 17 in the main Quoddy passage near Campobello the quantities were very much greater than in the "Channel" and near Calder beach greater still, being greatest at the very surface. It was at this place that the very fat fish were taken on July 7 that were full of food although they had been held in the weir for a week, the water in the weir being visibly crowded with food organisms, and feeling "gritty" owing to the large numbers of *Calanus*.

There is, therefore, clear evidence that food is generally available close to the

surface in the passages, though varying greatly in amount, and that the amount available is correlated with the local fatness of the herring, the fish being fatter and the near surface food more abundant at Campobello as compared with the "Channel". Also, going from the "Channel" into the Inner bay, there is a very marked decrease in the availability of food at the surface, and a decrease in total quantity and concentration of the plankton just as previously shown going from the main Quoddy passage to the Inner bay.

The report that herring are full of feed particularly after moonlight nights is made most definitely for the Inner bay, as at Navy island. It seemed desirable to ascertain how available the food in that vicinity might be both in daylight and in moonlight. Tows were taken on July 24, with a plankton net made of cotton voile with mesh corresponding to no. 5 bolting cloth, at various depths at each of three stations from the middle shoals just east of Navy island out toward the centre of the Inner bay (stations 23 to 25, figure 1). They were made in foggy weather between 8.30 and 10.30 a.m., and each was of 10 minutes' duration. The quantities of plankton are given in table XI.

TABLE XI. Quantities of plankton (cc.) taken with no. 5 net in the Inner bay on July 24, 1933

Depth (m.)	Station no.		
	23	24	25
0	5	5½	1
5	18	8	12½
10	23	14	11
20		13	9
30			8

It is evident from the quantities given in that table that the plankton is more concentrated and nearer the surface in the shallow water among the shoals where tidal stirring is pronounced than out in the bay. The surface layer is seen to have relatively little plankton even among the shoals, showing that the food organisms are brought to the surface less effectively at this point than in the passages at the mouth of the bay.

In early September tows were taken with the standard no. 0 net at three stations similar to the last from the neighbourhood of the shoals to the middle of the Inner bay (stations 42, 43, and 848, figure 1). The quantities of plankton obtained are shown in table XII. The comprehensive tows (quantities made comparable to a 10-minute tow) taken in sunlight reveal a much greater concentration of plankton in the 10-metre depth of station 42 near the shoals than in the 40-metre depths of the other two stations, thus agreeing with the results given in table XI. As the herring tend to be near the surface, but deeper in daytime than at night, the quantities near the surface are of chief importance. At 1 m. depth in sunlight, there is most plankton near the shoals, but little even there. In moonlight, however, there is from 7 to 10 times as much plankton at 1 m. depth at each station as in sunlight, the quantities, as in sunlight, decreasing from the shoals to the middle of the bay. At all stations there was less at the surface, but

at station 42 near the shoals there was very much more than elsewhere. The plankton consisted almost wholly of copepods, and mainly of the small species. The large ones (*Calanus*) were at 1 metre depth in the water mixed by tidal currents at station 42 even in sunlight, but in the unmixed water of station 848 they were not at 1 metre depth even in moonlight, though present in the deeper water as shown by the comprehensive tow. The moonlight tows at this station were made at 10 p.m. and repeated three hours later at 1.20 a.m. with the same result in quantity of plankton as well as in kinds of copepods.

These facts indicate that in the neighbourhood of the shoals near Navy island herring could get food near the surface much more readily on moonlight nights than in sunlight, while in the unmixed water in the middle of the Inner bay, they would have difficulty in getting food even on moonlight nights.

TABLE XII. Quantities of plankton (cc.) taken with no. 0 net in the Inner bay on September 5 (moonlight) and 8 (sunlight)

Tow	Station no.		
	42	43	848
Sunlight			
1 m. horiz.....	4	2	1½
Comprehensive (concentration)..	95	11	11
Moonlight			
0 m. horiz.....	14	4	1
1 m. "	28	18	15

GENERAL DISCUSSION

The herring are reported and found to be fattest in localities related to the main Quoddy passage. These are not the localities where herring are most regularly abundant, and they are in part localities where the herring are largest (Campobello), and in part those where the herring are smallest (Cobscook bay). They may be described as comparatively shallow inlets or bays on the convex side of the main passage. In this passage the principal food forms (*Calanus* and *Meganyctiphanes*) for the intermediate and larger sizes of herring are apparently to be found most regularly in greatest abundance, as well as at all depths. These forms have come from the gulf of Maine and it would appear that with the flooding tide they are carried in from the outer bay in the deeper water, are brought to the surface in the strong tidal rips of the main Quoddy passage and, while still near the surface, are swept through the comparatively shallow Friar roads into the shallow Cobscook bay, as well as up the deep Quoddy river or inner half of the main passage. The ebbing tide from both Cobscook bay and Quoddy river would, owing to the bending of the passages, be forced against the Campobello shore and into Friars bay and Harbour de Loutre. These inlets should accordingly be provided with an abundant supply of the best herring food as the facts demonstrate.

The waters around Deer island seem to be not quite so favourably situated for receiving the food and have more herring, which are accordingly less fat. A very important element in this region of the Quoddy passages between the Inner and Outer bays would be the occurrence of *Calanus* and *Meganyctiphanes* near the surface where the herring keep and are able to see and capture them throughout the long summer day as well as on moonlight nights. While the herring quite evidently requires light of the intensity of moonlight or better to enable it to capture its food, both *Calanus* and *Meganyctiphanes* are of deep-water habit, for the most part avoiding so much light. They require, therefore, to be brought near the surface if they are to serve at all extensively as food for the herring.

The comparative paucity of food in the Inner bay and St. Croix estuary is associated with on the whole a poorer condition of the herring. Such *Calanus* and *Meganyctiphanes* as do enter are made available (mainly with low illumination as in moonlight) to the herring at mixing places far in, as are also the local forms, so that intermediate places relatively devoid of mixing, such as the Perry shore on the west and the Mascareen shore on the east have poorer herring than would be expected from their proximity to the rich water in the passages. The principal food available inside consists of the endemic small copepods, suitable only for the smaller herring. This is to a certain extent a satisfactory condition seeing that the smaller fish prevail toward the head of the Inner bay. Unlike *Calanus*, these small copepods come to the surface of themselves, but differ greatly in their availability near the surface and in the relation of this availability to the amount of illumination.

Explanation of the reputed poor condition of the herring in Oak bay is not yet found, that district not having been sufficiently investigated. However, the herring are chiefly taken in its very shallow upper end, where operate none of the factors that provide good or relatively good feeding elsewhere.

It has been sufficiently demonstrated that to a fair extent the young herring in various localities of this region exhibit characteristic degrees of fatness and this in correlation with the local feeding conditions, which are neither the local production nor the local amount of food, but its availability to the herring. It may be produced in very distant places, namely the gulf of Maine, and yet made available to the herring far within Inner Passamaquoddy bay. To show the effect of the local conditions, the herring must on the whole remain a fair length of time in the particular locality. Some fishermen recognize this, observing that a new lot of fish appear and then rapidly fatten up in places where food is available to them in large quantities. By report, it takes a matter of weeks for the herring to become fat or lean. The temperature of the water during the important feeding season from June to August ranges from 6° to 11°C. (Huntsman 1934). The experiments already detailed have shown that at these temperatures it takes from 32 to 19 hours for full digestion to occur in herring of the commonest sizes in this region.

The herring have been taken in various parts of the region throughout the whole year, though they are progressively less available as the temperature drops. The facts fail to demonstrate any seasonal migration, properly speaking. On

the other hand, they indicate quite clearly that the fish, while moving about or being moved from place to place to a limited extent, tend to remain for weeks in one locality so as to exhibit a fatness characteristic of that locality.

SUMMARY

1. The condition factor $\frac{\text{weight (gm.)}}{\text{length (cm.)}^3} \times 100$ in Passamaquoddy herring is found to vary from about 0.5 to more than 1.0.

2. Localities distant from each other as little as a couple of miles (about 3 km.) are shown to have rather constant differences in the fatness of the herring as judged by the condition factor.

3. Herring take their food by an act of capture, coming up to it from below, when the light is from above.

4. Herring do not feed in darkness and feed more rapidly with increased illumination at intensities not far from that of moonlight.

5. The rate of digestion in the herring varies with temperature, a full stomach being cleared in from six to seven hours at 20° and only by $25\frac{1}{2}$ hours at 6°C. in herring 14 to 16 cm. long.

6. Small herring seem to require a longer time for clearing, 9-12 cm. fish taking about 14 hours at 14°C. as compared with $10\frac{1}{2}$ hours for fish 14 to 16 cm. long.

7. In localities where the herring are the fattest, they contain the most food, and of the larger kinds, such as *Calanus* and *Meganyctiphanes*.

8. Where the food is wholly of the smaller kinds, only the smaller fish contain it, and in general the size of the food corresponds with the size of the fish.

9. In some localities the herring have more food and of special kinds after moonlight nights.

10. The herring are mainly in the upper layers of water during the summer feeding season, and react to light, coming nearer the surface with low light intensities.

11. There is no general correlation betweeen the fatness of the herring and either the total amount of food organisms in a locality or the degree of their concentration in a locality.

12. However, a correlation exists between the fatness of the herring and the amount of food present near the surface.

13. In some localities the food organisms are much more abundant near the surface in moonlight than in sunlight, corresponding with more food in the herring after moonlight nights.

14. The food organisms are (*a*) most concentrated in the very thoroughly stirred waters of the passages at the mouth of the bay, (*b*) nearly as concentrated at mixing places in the bay, and (*c*) least so in parts of the bay where there is little mixing.

15. In the passages at the mouth of the bay and in inlets related to them,

deep-water food organisms (*Calanus*, *Meganyctiphanes*, etc.) of gulf of Maine origin are available at the surface at all times of the day, and sometimes in very large quantities.

16. Since the herring exhibit a fatness characteristic of the locality in which they are found, it is to be definitely inferred that on the whole they remain a matter of some weeks in the one place, and shift from place to place either very slowly or rarely.

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